BIOAVAILABILITY OF LEAD IN A SOIL SAMPLE FROM THE BUTTE NPL SITE BUTTE, MONTANA

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EXECUTIVE SUMMARY

A study using young swine as test animals was performed to measure the gastrointestinal absorption of lead from a soil sample from the Silver Bow Creek/ Butte Area National Priority List site in Butte, Montana. Young swine were selected for use in the study primarily because the gastrointestinal physiology and overall size of young swine are similar to that of young children, who are the population of prime concern for exposure to soil lead.

The test soil was a composite collected from within the Butte Priority Soils Operable Unit (BPSOU), focusing on the source areas of Little Mina-1, Little Mina-2, West Ruby and North Emma waste rock dumps. The sample contained 8,600 ppm lead. Groups of 5 swine were given average oral doses of 8.7, 26, or 79 mg/kg-d of soil for 15 days. This corresponded to target average doses of 75, 225, or 675 ug/kg/day of lead. Other groups of animals were given a standard lead reference material (lead acetate) either orally at doses of 0, 75 or 225 ug Pb/kg-day, or intravenously at a dose of 100 ug Pb/kg-day. The amount of lead absorbed by each animal was evaluated by measuring the amount of lead in the blood (measured on days -4, 0, 1, 2, 3, 5, 7, 9, 12, and 15), and the amount of lead in liver, kidney and bone (measured on day 15 at study termination). The amount of lead present in blood or tissues of animals exposed to the test soil was compared to that for animals exposed to lead acetate, and the results were expressed as relative bioavailability (RBA). For example, a relative bioavailability of 50% means that 50% of the lead in soil was absorbed equally as well as lead from lead acetate, and 50% behaved as if it were not available for absorption. Thus, if lead acetate were 40% absorbed, the test material would be 20% absorbed.

The RBA results for the sample from the Butte site are summarized below:

Measurement Endpoint	Butte Soil RBA for Lead
Blood Lead AUC	0.22
Liver Lead	0.09
Kidney Lead	0.13
Bone Lead	0.13

Because the estimates of RBA based on blood, liver, kidney, and bone do not agree in all cases, judgment must be used in interpreting the data. In general, we recommend greatest emphasis be placed on the RBA estimates derived from the blood lead data. This is because blood lead data are more robust and less susceptible to random errors than the tissue lead data, so there is greater confidence in RBA estimates based on blood lead. In addition, absorption into the central compartment is an early indicator of lead exposure, is the most relevant index of central nervous system exposure, and is the standard measurement endpoint in investigations of this sort. However, data from the tissue endpoints (liver, kidney, bone)

also provide valuable information. We consider the plausible range to extend from the RBA based on blood AUC to the mean of the other three tissues (liver, kidney, bone). The preferred range is the interval from the RBA based on blood to the mean of the blood RBA and the tissue mean RBA. Our suggested point estimate is the mid-point of the preferred range. These values are presented below:

RBA Estimate	Value
Plausible Range	0.12 - 0.22
Preferred Range	0.17 - 0.22
Suggested Point Estimate	0.19

These RBA estimates may be used to help assess lead risk at this site by refining the estimate of absolute bioavailability (ABA) of lead in soil, as follows:

$$ABA_{soil} = ABA_{soluble} \cdot RBA_{soil}$$

Available data indicate that fully soluble forms of lead are about 50% absorbed by a child. Thus, the estimated absolute bioavailability of lead in the sample is as follows:

Absolute Bioavailability of Lead	Butte Soil Test material
Plausible Range	6%-11%
Preferred Range	8%-11%
Suggested Point Estimate	10%

These absolute bioavailability estimates are appropriate for use in EPA's IEUBK model for this site, although it is clear that there is both natural variability and uncertainty associated with these estimates. This variability and uncertainty arises from several sources, including : 1) the inherent variability in the responses of different individual animals to lead exposure, 2) uncertainty in the relative accuracy and applicability of the different measurement endpoints, 3) the extrapolation of measured RBA values in swine to young children, and 4) the potential effect of food in the stomach on lead absorption. Thus, the values reported above are judged to be reasonable estimates of typical lead absorption by children at this site, but should be interpreted with the understanding that the values are not certain.

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Mineral Phase	Particle Freq.(%)		Particle Size[d] (um)			Relative Lead Mass [e] (%)
	Count-Based[b]	Length-Weighted[c]	min	max	mean	
Al-SiO_4	0.3	0.7	45	100	73	0.1
Anglesite	21.7	7.5	1	100	12	36.2
Cerrusite	0.2	0.05	10	10	10	0.3
Clay	0.2	0.14	30	30	30	0.0
Fe-Pb Oxide	5.8	10.5	4	180	61	7.0
Galena	5.8	1.7	1	55	10	12.5
Mn-Pb Oxide	25.4	32.8	3	200	44	20.2
Pb Barite	0.2	0.02	5	5	5	0.0
Pb Phosphate	1.9	3.0	5	200	54	3.6
Fe-Pb Sulfate	38.6	43.6	2	250	38	20.1

[a] Samples were analyzed using an electron microprobe (JEOL 8600) to identify the number of particles of each lead species present in each sample and the particle size (largest dimension) of each particle.

[b] Percentage of all lead-bearing particles of the mineral form shown

[c] Percentage of total length of all lead particles consisting of mineral form shown

[d] Based on longest dimension of each particle

[e] Rough estimate of the percent of the total mass of lead present in each mineral form

FIGURE 2-1 LEAD MINERALS OBSERVED IN TEST MATERIAL

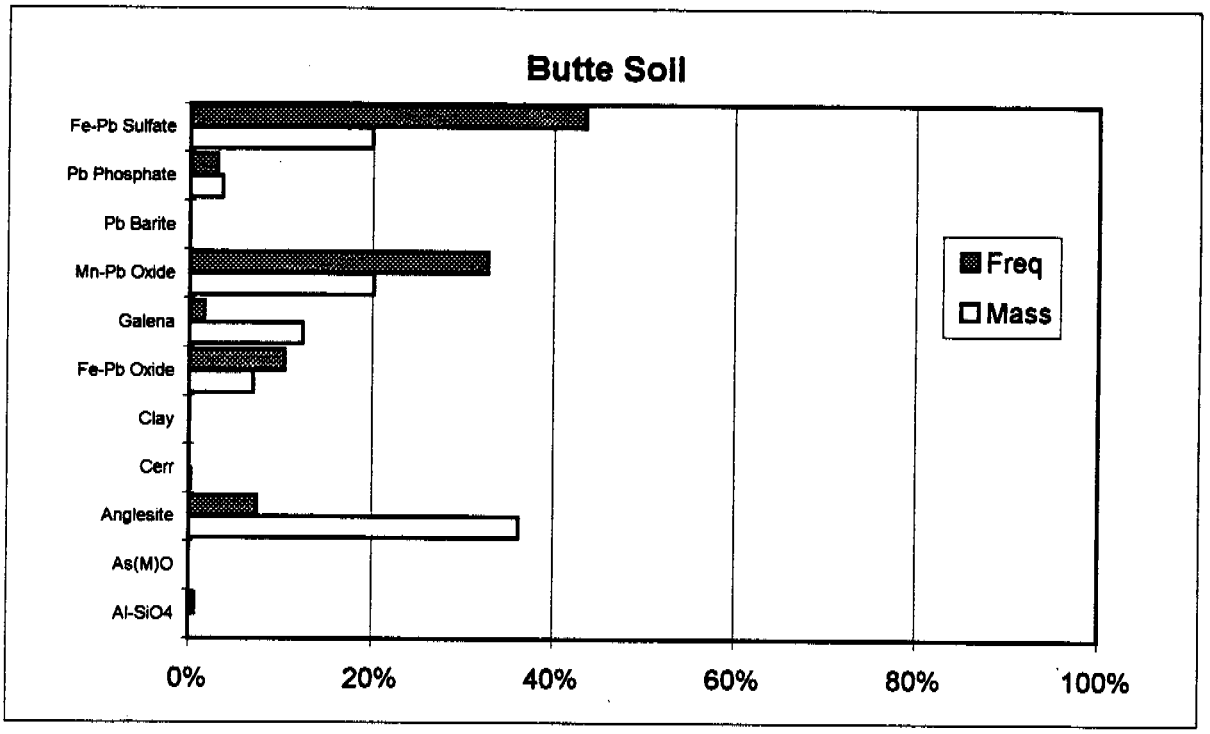

TABLE 2-1 METAL ANALYSIS OF TEST MATERIAL

Chemical	Concentration[a] (ppm)
Aluminum	7,800
Antimony	8.4
Arsenic	240
Barium	140
Beryllium	0.59
Cadmium	43
Calcium	16,000
Chromium	7.2
Cobalt	9.4
Copper	850
Iron	50,000
Lead	**8,600**
Magnesium	3,000
Manganese	13,000
Mercury	2.2
Nickel	8.7
Potassium	3,600
Selenium	0.28
Silver	41
Sodium	530
Thallium	1.8
Vanadium	28
Zinc	12,000

[a] Mean of analyses of original sample and a split; all values rounded to two significant figures

2.0 STUDY DESIGN

A standardized study protocol for measuring absolute and relative bioavailability of lead was developed based upon previous study designs and investigations that characterized the young pig model (Weis et al. 1995). The study was performed as nearly as possible within the spirit and guidelines of Good Laboratory Practices (GLP: 40 CFR 792). Standard Operating Procedures (SOPs) that included detailed methods for all aspects of the study were prepared, approved, and distributed to all study members prior to the study. The generalized study design, quality assurance project plan and all standard operating procedures are documented in a project notebook that is available through the administrative record.

2.1 Test Material

The soil sample tested in this study was a composite collected from the Butte Priority Soils Operable Unit (BPSOU) of the Silver Bow Creek/ Butte Area NPL Site in Butte, Montana. The sampling investigation focused on four source areas: the Little Mina-1, Little Mina-2, West Ruby and North Emma waste rock dumps. At each source area, five sub-samples were collected and composited, and these were then further composited across source areas to yield the sample used in the study. The composite was prepared for administration to the animals by air drying (maximum temperature = 40°C) followed by sieving through a nylon mesh to yield particles less than about 250 um. This was done because it is believed that fine particles are most likely to adhere to the hands and be ingested by hand-to-mouth contact, and are most likely to be available for absorption. Grinding was not employed.

The sample was split into two portions and a portion of each was analyzed for metals using standard EPA Contract Laboratory program (CLP) methods. The results (the mean of the two analyses) are shown in Table 2-1.

The soil was well mixed and analyzed by electron microprobe in order to identify a) how frequently particles of various lead minerals were observed, b) how frequently different types of mineral particles occur entirely inside particles of rock or slag ("included") and how often they occur partially or entirely outside rock or slag particles ("liberated"), c) the size distribution of particles of each mineral class, and d) approximately how much of the total amount of lead in the sample occurs in each mineral type. This is referred to as "relative lead mass". The results are summarized in Figure 2-1 and in Table 2-2.

As seen in Figure 2-1, the most common lead-bearing particle types (i.e, those which are observed most often) were iron-lead sulfate and manganese-lead oxide. Of the relative lead mass in the sample, most occurred in the form of anglesite (lead sulfate), with the remainder being composed mostly of iron-lead sulfate and manganese-lead oxide.

Figure 2-2 shows the distribution of the size of lead-bearing particles in the sample. As seen, there was a fairly broad distribution of lead-bearing particle sizes, with approximately 90% being less than 100 um in diameter, and 75% less than 50 um. As noted above, small particles are

Using Bioavailability Data to Improve Exposure Calculations for Lead

Data on bioavailability are important for evaluating exposure and potential health effects for a variety of different types of chemicals. This investigation focused mainly on evaluating the bioavailability of lead in various samples of soil or other solid materials from mining, milling or smelting sites. This is because lead may exist, at least in part, as poorly water soluble minerals (e.g., galena), and may also exist inside particles of inert matrix such as rock or slag of variable size, shape and association. These chemical and physical properties may tend to influence (usually decrease) the solubility (bioaccessability) and the absorption (bioavailability) of lead when ingested.

When data are available on the bioavailability of lead in soil, dust, or other soil-like waste material at a site, this information can often be used to improve the accuracy of exposure and risk calculations at that site. The basic equation for estimating the site-specific ABA of a test soil is as follows:

$$ABA_{soil} = ABA_{soluble} \cdot RBA_{soil}$$

where:

ABA_{soil} = Absolute bioavailability of lead in soil ingested by a child
$ABA_{soluble}$ = Absolute bioavailability in children of some dissolved or fully soluble form of lead
RBA_{soil} = RBA for soil measured in swine

Based on available information on lead absorption in humans and animals, the EPA estimates that the absolute bioavailability of lead from water and other fully soluble forms of lead is usually about 50% in children. Thus, when a reliable site-specific RBA value for soil is available, it may be used to estimate a site-specific absolute bioavailability as follows:

$$ABA_{soil} = 50\% \cdot RBA_{soil}$$

In the absence of site-specific data, the absolute absorption of lead from soil, dust and other similar media is estimated by EPA to be about 30%. Thus, the default RBA used by EPA for lead in soil and dust compared to lead in water is 30%/50% = 60%. When the measured RBA in soil or dust at a site is found to be less than 60% compared to some fully soluble form of lead, it may be concluded that exposures to and risks from lead in these media at that site are probably lower than typical default assumptions. If the measured RBA is higher than 60%, absorption of and risk from lead in these media may be higher than usually assumed.

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1.0 INTRODUCTION

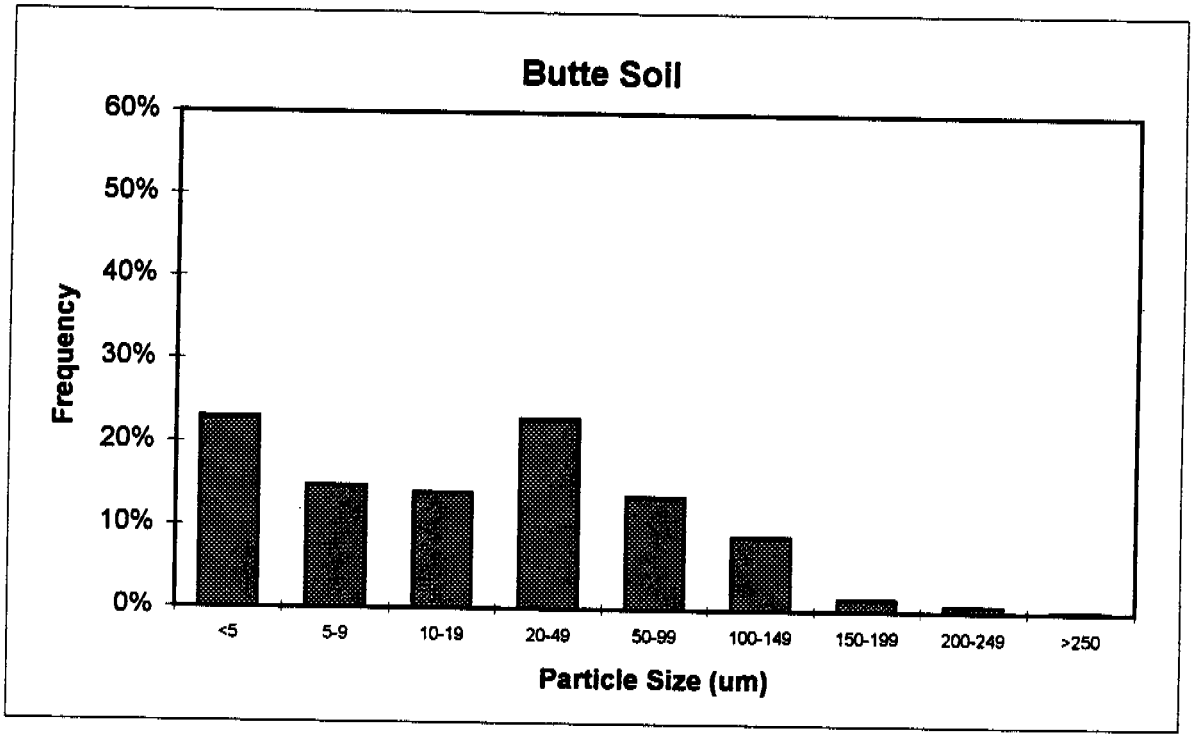
Absolute and Relative Bioavailability

Bioavailability is a concept that relates to the absorption of chemicals and how absorption depends upon the physical-chemical properties of the chemical and its medium (e.g., dust, soil, rock, food, water, etc.) and the physiology of the exposed receptor. Bioavailability is normally described as the fraction (or percentage) of a chemical which enters into the blood following an exposure of some specified amount, duration and route (usually oral). In some cases, bioavailability may be measured using chemical levels in peripheral tissues such as liver, kidney, and bone, rather than blood. The fraction or percentage absorbed may be expressed either in absolute terms (absolute bioavailability, ABA) or in relative terms (relative bioavailability, RBA). **Absolute bioavailability** is measured by comparing the amount of chemical entering the blood (or other tissue) following oral exposure to test material with the amount entering the blood (or other tissue) following intravenous exposure to an equal amount of some dissolved form of the chemical. Similarly, **relative bioavailability** is measured by comparing oral absorption of test material to oral absorption of some fully soluble form of the chemical (e.g., either the chemical dissolved in water, or a solid form that is expected to fully dissolve in the stomach). For example, if 100 ug of dissolved lead were administered in drinking water and a total of 50 ug entered the blood, the ABA would be 0.50 (50%). Likewise, if 100 ug of lead in soil were administered and 30 ug entered the blood, the ABA for soil would be 0.30 (30%). If the lead dissolved in water were used as the reference substance for describing the relative amount of lead absorbed from soil, the RBA would be 0.30/0.50 = 0.60 (60%). These values (50% absolute bioavailability of dissolved lead and 30% absolute absorption of lead in soil) are the values currently employed as defaults in EPA's IEUBK model.

It is important to recognize that simple solubility of a test material in water or some other fluid (e.g., a weak acid intended to mimic the gastric contents of a child) may not be a reliable estimator of bioavailability due to the non-equilibrium nature of the dissolution and transport processes that occur in the gastrointestinal tract (Mushak 1991). For example, transport of lead across the gut may continuously shift the equilibrium of a poorly soluble lead compound in the direction of dissolution. However, information on the solubility of lead in different materials is useful in interpreting the importance of solubility as a determinant of bioavailability. To avoid confusion, the term "bioaccessability" is used to refer to the relative amount of lead that dissolves under a specified set of test conditions.

For additional discussion about the concept and application of bioavailability see Goodman et al. (1990), Klaassen et al. (1996), and/or Gibaldi and Perrier (1982).

FIGURE 2-2 PARTICLE SIZE DISTRIBUTION



often assumed to be more likely to adhere to the hands and be ingested and/or be transported into the house. Further, small particles have larger surface area-to-volume ratios than larger particles, and so may tend to dissolve more rapidly in the acidic contents of the stomach than larger particles. Thus, small particles (e.g. less than 50-100 um) are thought to be of greater potential concern to humans than larger particles (e.g., 100-250 um or larger).

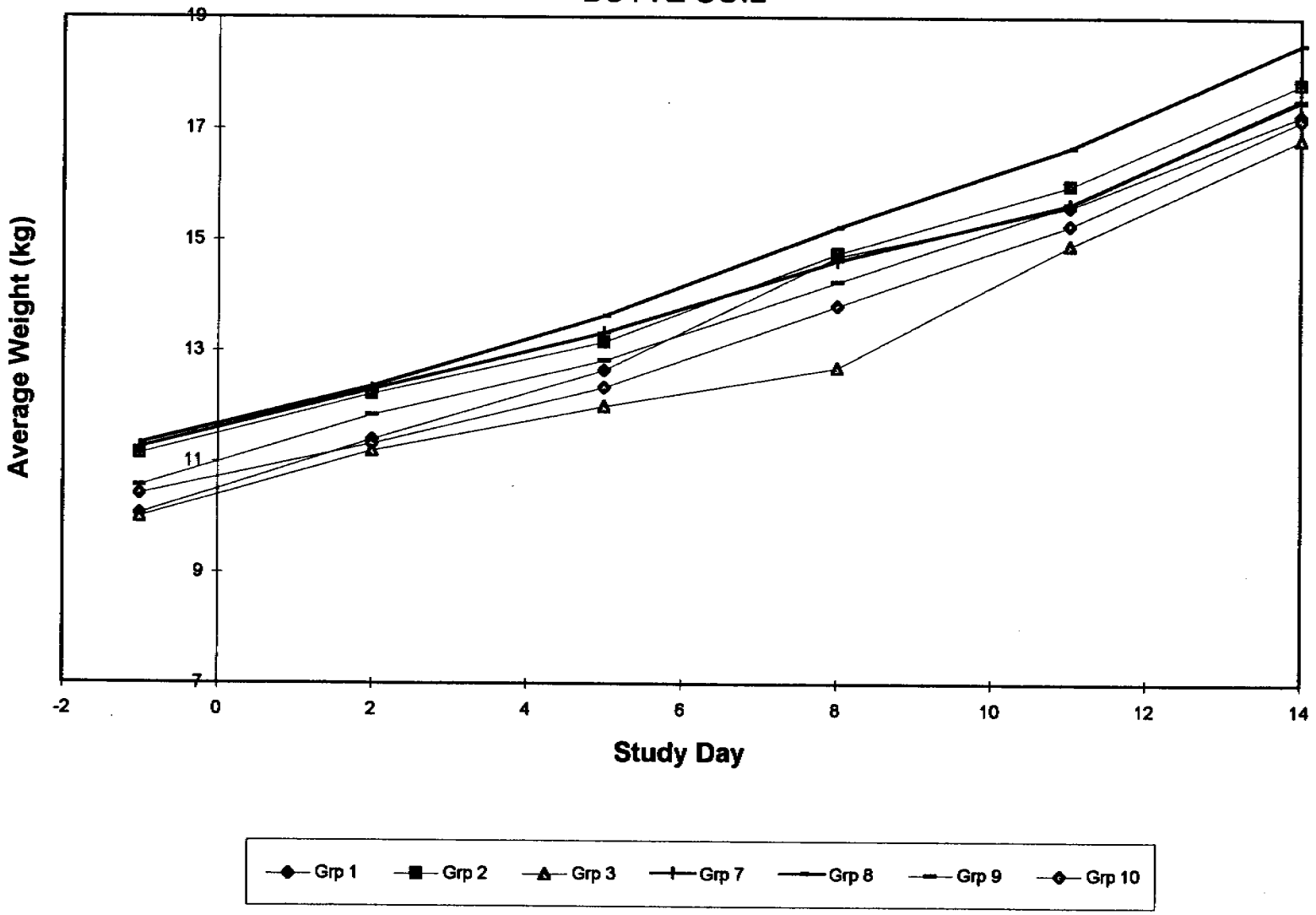
Another property of lead particles that may be important in determining bioaccessability and/or bioavailability is the degree to which they are partially or entirely free from surrounding matrix ("liberated"). Based on the measured frequency of each type of particle existing in a liberated state, it can be calculated that of the total relative lead present in the sample, about 88% exists in liberated particles, mainly in the form of anglesite, iron-lead sulfate and manganese-lead oxide. These high percentages of partially or entirely liberated grains may tend to increase the bioavailability of lead in this sample.

2.2 Experimental Animals

Young swine were selected for use in these studies because they are considered to be a good physiological model for gastrointestinal absorption in children (Weis and LaVelle 1991). The animals were intact males of the Pig Improvement Corporation (PIC) genetically defined Line 26, and were purchased from Chinn Farms, Clarence, MO. The animals were held under quarantine to observe their health for one week before beginning exposure to test materials. To minimize weight variations between animals and groups, the number of animals purchased from the supplier was six more than needed for the study, and the six animals most different in body weight on day -4 (either heavier or lighter) were excluded from further study. The remaining animals were assigned to dose groups at random. When exposure began, the animals were about 5-6 weeks old (juveniles, weaned at 3 weeks) and weighed an average of about 10.9 kg. Animals were weighed every three days during the course of the study. The group mean body weights over the course of the study are shown in Figure 2-3. As seen, on average, animals gained about 0.5 kg/day, and the rate of weight gain was comparable in all groups.

All animals were housed in individual lead-free stainless steel cages. Each animal was examined by a certified veterinary clinician (swine specialist) prior to being placed on study, and all animals were examined daily by an attending veterinarian while on study. Any animal that displayed significant signs of illness was given appropriate treatment, and was removed from study if the illness could not be promptly controlled. (This only occurred rarely, and usually only in animals with surgically-implanted venous catheters). Blood samples were collected for hematological analysis on days -4, 7, and 15 to assist in clinical health assessments. In this study, there were no animals that were judged by the principle investigator and the veterinary clinician to be seriously ill, and no animals were removed from the study due to concerns over poor health.

FIGURE 2-3 BODY WEIGHTS OF TEST ANIMALS
BUTTE SOIL



2.3 Diet

Animals provided by the supplier were weaned onto standard pig chow purchased from MFA Inc., Columbia, MO. In order to minimize lead exposure from the diet, the animals were gradually transitioned from the MFA feed to a special low-lead feed (guaranteed less than 0.2 ppm lead, purchased from Zeigler Brothers, Inc., Gardners, PA) over the time interval from day -7 to day -3, and this feed was then maintained for the duration of the study. The feed was nutritionally complete and met all requirements of the National Institutes of Health-National Research Council. The typical nutritional components and chemical analysis of the feed are presented in Table 2-3. Typically, the feed contained approximately 5.7% moisture, 1.7% fiber, and provided about 3.4 kcal of metabolizable energy per gram. Periodic analysis of feed samples during this program indicated the mean lead level (treating non-detects at one-half the quantitation limit of 0.05 ppm) was less than 0.05 ppm.

Each day every animal was given an amount of feed equal to 5% of the mean body weight of all animals on study. Feed was administered in two equal portions of 2.5% of the mean body weight at each feeding. Feed was provided at 11:00 AM and 5:00 PM daily. Drinking water was provided ad libitum via self-activated watering nozzles within each cage. Periodic analysis of samples from randomly selected drinking water nozzles indicated the mean lead concentration (treating non-detects at one-half the quantitation limit) was less than 2 ug/L.

2.4 Dosing

The protocol for exposing animals to lead is shown in Table 2-4. Animals were exposed to lead for 15 days, with the dose for each day being administered in two equal portions given at 9:00 AM and 3:00 PM (two hours before feeding). Doses were based on measured group mean body weights, and were adjusted every three days to account for animal growth. For animals exposed by the oral route, dose material was placed in the center of a small portion (about 5 grams) of moistened feed, and this was administered to the animals by hand. Most animals consumed the dose promptly, but occasionally some animals delayed ingestion of the dose for up to two hours (the time the daily feed portion was provided). These delays are noted in the data provided in Appendix A, but are not considered to be a significant source of error. Occasionally, some animals did not consume some or all of the dose (usually because the dose dropped from their mouth while chewing). All missed doses were recorded and the time-weighted average dose calculation for each animal was adjusted downward accordingly. Any animal that missed 5 or more of the 30 total oral doses administered during the study was excluded from data analysis. There were no animals that missed doses in this study.

For animals exposed by intravenous injection, doses were given via a vascular access port (VAP) attached to an indwelling venous catheter that had been surgically implanted according to standard operating procedures by a board-certified veterinary surgeon through the external jugular vein to the cranial vena cava about 3 to 5 days before exposure began.

TABLE 2-3 TYPICAL FEED COMPOSITION[a]

Nutrient Name	Amount	Nutrient Name	Amount
Protein	20.1021%	Chlorine	0.1911%
Arginine	1.2070%	Magnesium	0.0533%
Lysine	1.4690%	Sulfur	0.0339%
Methionine	0.8370%	Manganese	20.4719 ppm
Met+Cys	0.5876%	Zinc	118.0608 ppm
Tryptophan	0.2770%	Iron	135.3710 ppm
Histidine	0.5580%	Copper	8.1062 ppm
Leucine	1.8160%	Cobalt	0.0110 ppm
Isoleucine	1.1310%	Iodine	0.2075 ppm
Phenylalanine	1.1050%	Selenium	0.3196 ppm
Phe+Tyr	2.0500%	Nitrogen Free Extract	60.2340%
Threonine	0.8200%	Vitamin A	5.1892 kIU/kg
Valine	1.1910%	Vitamin D3	0.6486 kIU/kg
Fat	4.4440%	Vitamin E	87.2080 IU/kg
Saturated Fat	0.5590%	Vitamin K	0.9089 ppm
Unsaturated Fat	3.7410%	Thiamine	9.1681 ppm
Linoleic 18:2:6	1.9350%	Riboflavin	10.2290 ppm
Linoleic 18:3:3	0.0430%	Niacin	30.1147 ppm
Crude Fiber	3.8035%	Pantothenic Acid	19.1250 ppm
Ash	4.3347%	Choline	1019.8600 ppm
Calcium	0.8675%	Pyridoxine	8.2302 ppm
Phos Total	0.7736%	Folacin	2.0476 ppm
Available Phosphorous	0.7005%	Biotin	0.2038 ppm
Sodium	0.2448%	Vitamin B12	23.4416 ppm
Potassium	0.3733%		

[a] Nutritional values provided by Zeigler Bros., Inc.

TABLE 2-4 DOSING PROTOCOL

Group[a]	Number of Animals	Dose Material Administered	Exposure Route	Lead Dose (ug Pb/kg-d)	
				Target	Actual[b]
1	2	None	Oral	0	0
2	5	Lead acetate	Oral	75	76.5
3	5	Lead acetate	Oral	225	252
7	5	Butte soil	Oral	75	74.2
8	5	Butte soil	Oral	225	227
9	5	Butte soil	Oral	675	688
10	8	Lead acetate	Intravenous	100	102

Doses were administered in two equal portions given at 9:00 AM and 3:00 PM each day. Doses were based on the mean weight of the animals in each group, and were adjusted every three days to account for weight gain.

[a] Groups 4-6 not shown; data for samples from another site

[b] Calculated as the administered daily dose divided by the measured or extrapolated daily body weight, averaged over days 0-14 for each animal and each group.

Actual mean doses, calculated from the administered doses and the measured body weights, are also shown in Table 2-4.

2.5 Collection of Biological Samples

Blood

Samples of blood were collected from each animal four days before exposure began (day -4), on the first day of exposure (day 0), and on days 1, 2, 3, 5, 7, 9, 12, and 15 following the start of exposure. All blood samples were collected by vena-puncture of the anterior vena cava, and samples were immediately placed in purple-top Vacutainer® tubes containing EDTA as anticoagulant. Blood samples were collected each sampling day beginning at 8:00 AM, approximately one hour before the first of the two daily exposures to lead on the sampling day and 17 hours after the last lead exposure the previous day. This blood collection time was selected because the rate of change in blood lead resulting from the preceding exposures is expected to be relatively small after this interval (LaVelle et al. 1991, Weis et al. 1993), so the exact timing of sample collection relative to last dosing is not likely to be critical.

Following collection of the final blood sample at 8:00 AM on day 15, all animals were humanely euthanized and samples of liver, kidney, and bone (the right femur) were removed and stored in lead-free plastic bags for lead analysis. Samples of all biological samples collected were archived in order to allow for later reanalysis and verification, if needed. All animals were also subjected to detailed examination at necropsy by a certified veterinary pathologist in order to assess overall animal health.

2.6 Preparation of Biological Samples for Analysis

Blood

One mL of whole blood was removed from the purple-top Vacutainer and added to 9.0 mL of "matrix modifier", a solution recommended by the Centers for Disease Control and Prevention (CDCP) for analysis of blood samples for lead. The composition of matrix modifier is 0.2% (v/v) ultrapure nitric acid, 0.5% (v/v) Triton X-100, and 0.2% (w/v) dibasic ammonium phosphate in deionized and ultrafiltered water. Samples of the matrix modifier were routinely analyzed for lead to ensure the absence of lead contamination.

Liver and Kidney

One gram of soft tissue (liver or kidney) was placed in a lead-free screw-cap teflon container with 2 mL of concentrated (70%) nitric acid and heated in an oven to 90°C overnight. After cooling, the digestate was transferred to a clean lead-free 10 mL volumetric flask and diluted to volume with deionized and ultrafiltered water.

Bone

The right femur of each animal was removed and defleshed, and dried at 100°C overnight. The dried bones were then placed in a muffle furnace and dry-ashed at 450°C for 48 hours. Following dry ashing, the bone was ground to a fine powder using a lead-free mortar and pestle, and 200 mg was removed and dissolved in 10.0 mL of 1:1 (v:v) concentrated nitric acid:water. After the powdered bone was dissolved and mixed, 1.0 mL of the acid solution was removed and diluted to 10.0 mL by addition of 0.1% (m/v) lanthanum oxide (La_2O_3) in deionized and ultrafiltered water.

2.7 Lead Analysis

Samples of biological tissue (blood, liver, kidney, bone) and other materials (food, water, reagents and solutions, etc.) were arranged in a random sequence and provided to EPA's analytical laboratory in a blind fashion (identified to the laboratory only by a chain of custody tag number). Each sample was analyzed for lead using a Perkin Elmer Model 5100 graphite furnace atomic absorption spectrophotometer. Internal quality assurance samples were run every tenth sample, and the instrument was recalibrated every 15th sample. A blank, duplicate and spiked sample were run every 20th sample.

All results from the analytical laboratory were reported in units of ug Pb/L of prepared sample. The quantitation limit was defined as three-times the standard deviation of a set of seven replicates of a low-lead sample (typically about 2-5 ug/L). The standard deviation was usually about 0.3 ug/L, so the quantitation limit was usually about 0.9-1.0 ug/L (ppb). For prepared blood samples (diluted 1/10), this corresponds to a quantitation limit of 10 ug/L (1 ug/dL). For soft tissues (liver and kidney, diluted 1/10), this corresponds to a quantitation limit of 10 ug/kg (ppb) wet weight, and for bone (final dilution = 1/500) the corresponding quantitation limit is 0.5 ug/g (ppm) ashed weight.

3.0 DATA ANALYSIS

3.1 Overview

Studies on the absorption of lead are often complicated because some biological responses to lead exposure may be non-linear functions of dose (i.e., tending to flatten out or plateau as dose increases). The cause of this non-linearity is uncertain but might be due either to non-linear **absorption kinetics** and/or to non-linear **biological response** per unit dose absorbed. When the dose-response curve for either the reference material (lead acetate) and/or the test material is non-linear, RBA is equal to the ratio of doses that produce equal responses (not the ratio of responses at equal doses). This is based on the simple but biologically plausible assumption that equal absorbed doses yield equal biological responses. Applying this assumption leads to the following general methods for calculating RBA from a set of non-linear experimental data:

1. Plot the biological responses for individual animals exposed to a series of oral doses of soluble lead (e.g., lead acetate). Find an equation which gives a smooth best fit line through the observed data.

2. Plot the biological response for individual animals exposed to a series of doses of test material. Find an equation which gives a smooth fit line through the observed data.

3. Using the best fit equations for reference material and test material, calculate RBA as the ratios of doses of test material and reference material which yield equal biological responses. Depending on the relative shape of the best-fit lines through the lead acetate and test material dose response curves, RBA may either be constant (dose-independent) or variable (dose-dependent).

The principal advantage of this approach is that it is not necessary to understand the basis for a non-linear dose response curve (non-linear absorption and/or non-linear biological response) in order to derive valid RBA estimates. Also, it is important to realize that this method is very general, as it will yield correct results even if one or both of the dose-response curves are linear. In the case where both curves are linear, RBA is dose-independent and is simply equal to the ratio of the slopes of the best-fit linear equations.

3.2 Fitting the Curves

There are a number of different mathematical equations which can yield reasonable fits with the dose-response data sets obtained in this study. In selecting which equations to employ, the following principles were applied: 1) mathematically simple equations were preferred over mathematically complex equations, 2) the shape of the curves had to be smooth and biologically realistic, without inflection points, maxima or minima, and 3) the general form of the equations had to be able to fit data not only from this one study, but from all the studies that are part of

this project. After testing a wide variety of different equations, it was found that all data sets could be well fitted using one of the following three forms:

Linear (LIN): $\text{Response} = a + b \cdot \text{Dose}$

Exponential (EXP): $\text{Response} = a + c \cdot (1-\exp(-d \cdot \text{Dose}))$

Combination (LIN+EXP): $\text{Response} = a + b \cdot \text{Dose} + c \cdot (1-\exp(-d \cdot \text{Dose}))$

Although underlying mechanism was not considered in selecting these equations, the linear equation allows fitting data that do not show evidence of saturation in either uptake or response, while the exponential and mixed equations allow evaluation of data that appear to reflect some degree of saturation in uptake and/or response.

Each dose-response data set was fit to each of the equations above. If one equation yielded a fit that was clearly superior (as judged by the value of the adjusted correlation coefficient R^2) to the others, that equation was selected. If two or more models fit the data approximately equally well, then the simplest model (that with the fewest parameters) was selected. In the process of finding the best-fits of these equations to the data, the values of the parameters (a, b, c, and d) were subjected to some constraints, and some data points (those that were outside the 95% prediction limits of the fit) were excluded. These constraints and outlier exclusion steps are detailed in Appendix A (Section 3). In general, most blood lead AUC dose-response curves were best fit by the exponential equation, and most dose-response curves for liver, kidney, and bone were best fit by linear equations.

3.3 Responses Below Quantitation Limit

In some cases, most or all of the responses in a group of animals were below the quantitation limit for the endpoint being measured. For example, this was normally the case for blood lead values in unexposed animals (both on day -4 and day 0, and in control animals), and also occurred during the early days in the study for animals given test materials with low bioavailability. In these cases, all animals which yielded responses below the quantitation limit were evaluated as if they had responded at one-half the quantitation limit.

3.4 Quality Assurance

A number of steps were taken throughout this study and the other studies in this project to ensure the quality of the results. These steps are summarized below.

Duplicates

A randomly selected set of about 5% of all samples generated during the study were submitted to the laboratory in a blind fashion for duplicate analysis. The raw data are presented in

Appendix A, and Figure 3-1 plots the results for blood (Panel A, upper) and for bone, liver and kidney (Panel B, lower). As seen, there was good intra-laboratory reproduciblity between duplicate samples for all tissues, with linear regression lines having a slope near 1.0, an intercept near zero, and an R^2 value very near 1.00.

Standards

The Centers for Disease Control and Prevention (CDCP) provide a variety of blood lead "check samples" for use in quality assurance programs for blood lead studies. Each time a group of blood samples was prepared and sent to the laboratory for analysis, several CDCP check samples of different concentrations were included in random order and in a blind fashion.

The results for the samples submitted during this study are presented in Appendix A, and the values are plotted in Figure 3-2 (Panel A, upper). As seen, the analytical results obtained for the check samples were generally good at all three concentrations, with mean results of 1.5 ug/L for the low standards (nominal = 1.7 ug/L), 4.7 ug/L for the middle standard (nominal = 4.8 ug/L), and 14.1 ug/L for the high standards (nominal = 14.9 ug/L).

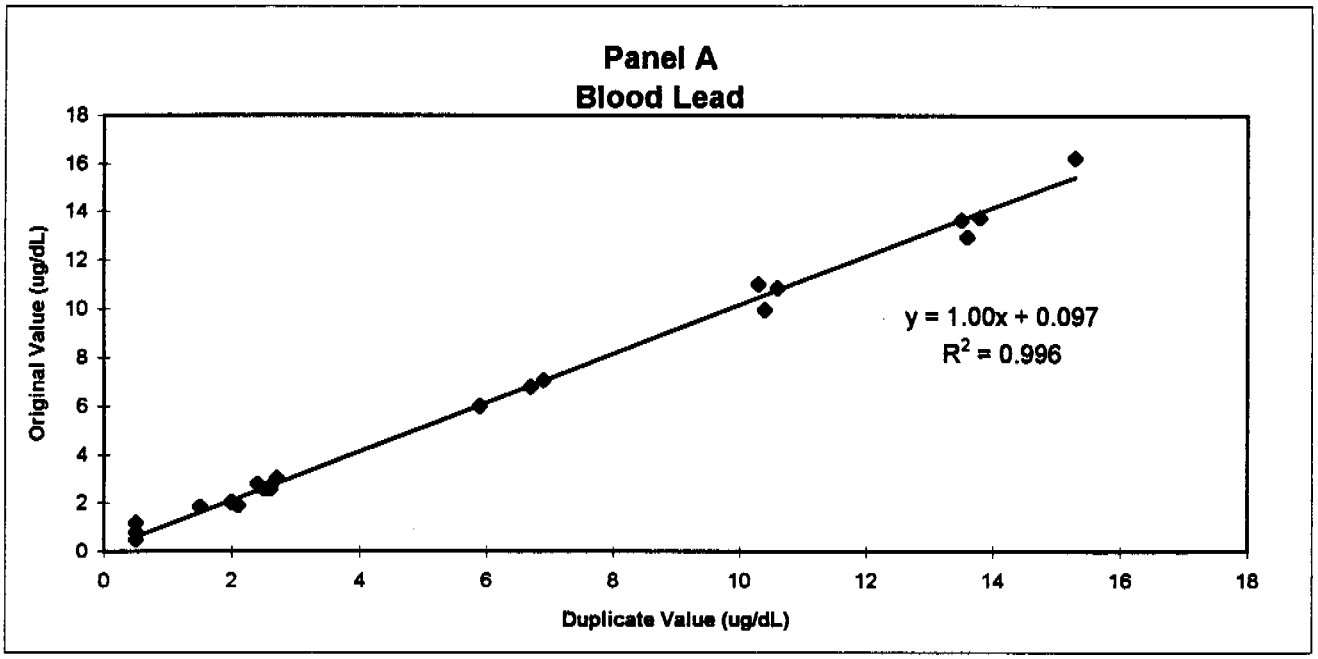
Interlaboratory Comparison

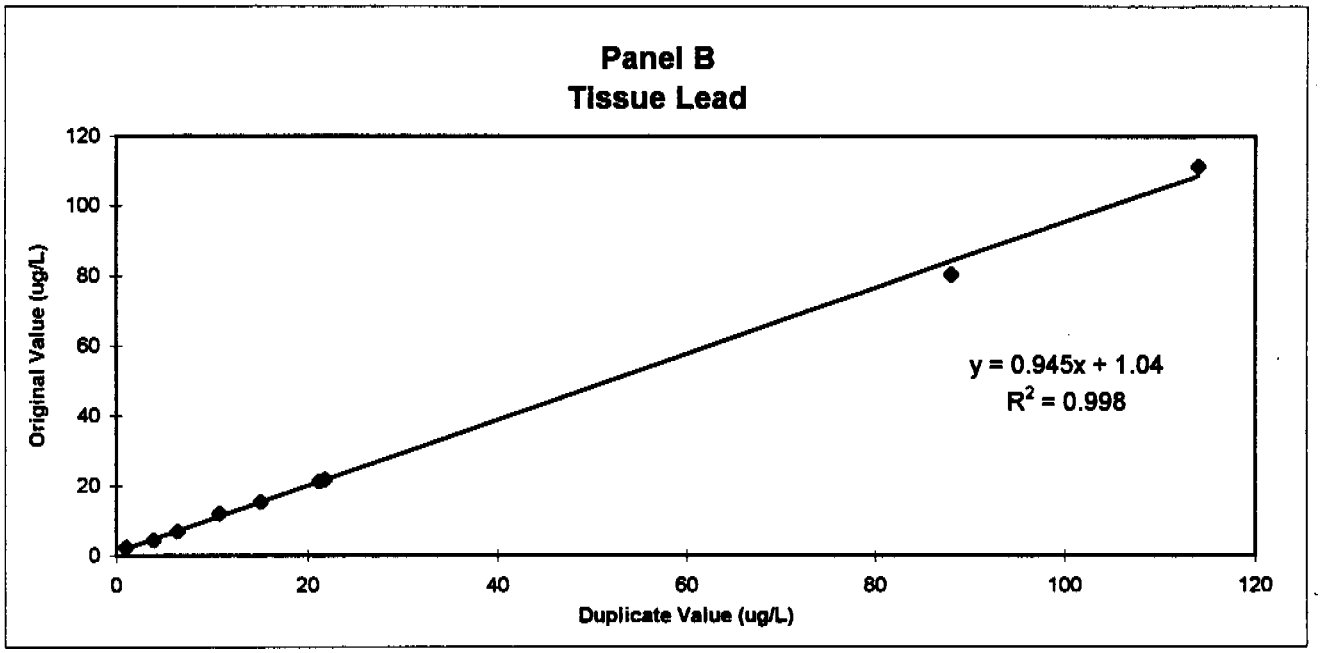
An interlaboratory comparison of blood lead analytical results was performed by sending a set of 20 randomly selected whole blood samples from this study to CDCP for blind independent preparation and analysis. The results are presented in Appendix A, and the values are plotted in Figure 3-2 (Panel B, lower). As seen, the results of analyses by EPA's laboratory are generally similar to those of CDCP, with a mean inter-sample difference of 0.16 ug/L. The slope of the best-fit straight line through the data is 0.74 if all of the data points are included, but is 0.86 if one data point (shown by an open diamond in Panel B) for which the CDPC result (9.6 ug/L) was noticeably higher than the EPA result (6.6 ug/L) is excluded.

Data Audits and Spreadsheet Validation

All analytical data generated by EPA's analytical laboratory were validated prior to being released in the form of a database file. These electronic data files were "decoded" (linking the sample tag to the correct animal and day) using Microsoft's database system ACCESS® (Version 5 for Windows). To ensure that no errors occurred in this process, original downloaded electronic files were printed out and compared to printouts of the tag assignments and the decoded data. All spreadsheets used to manipulate the data and to perform calculations (see Appendix A) were validated by hand-checking random cells for accuracy.

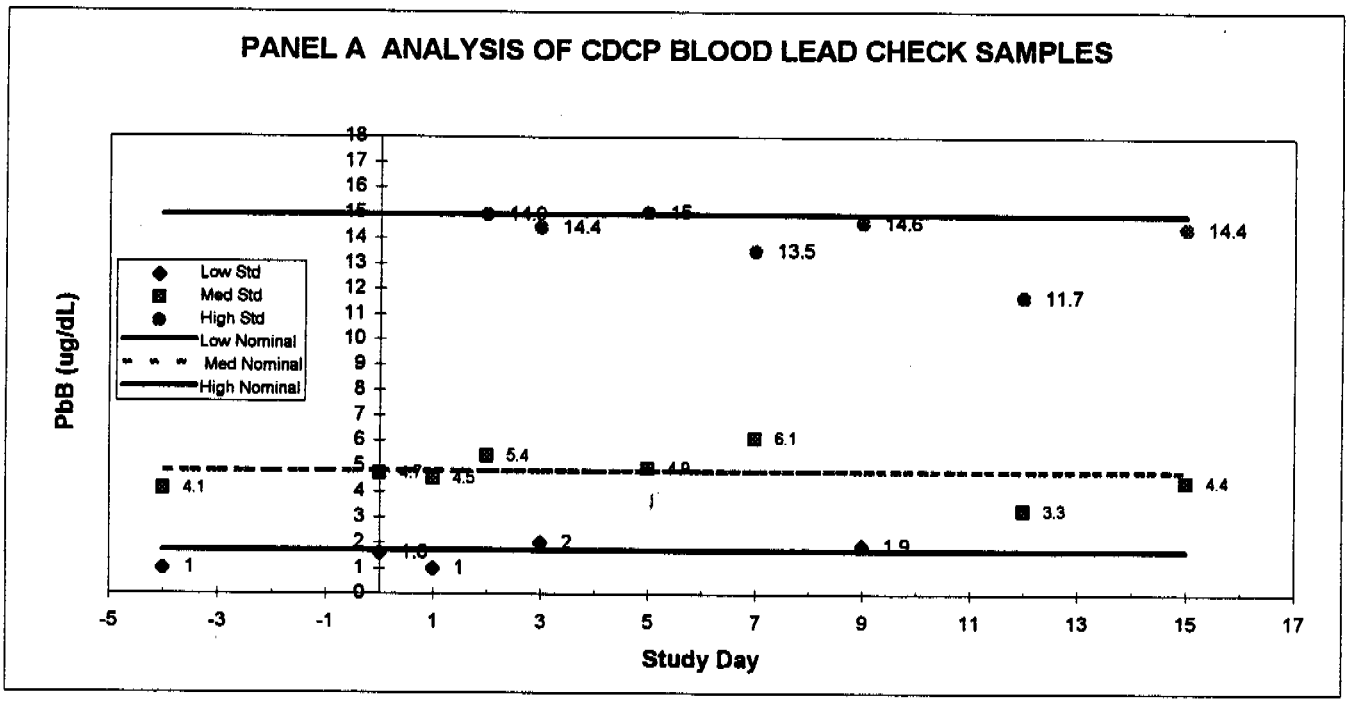
FIGURE 3-1 COMPARISION OF DUPLICATE ANALYSES

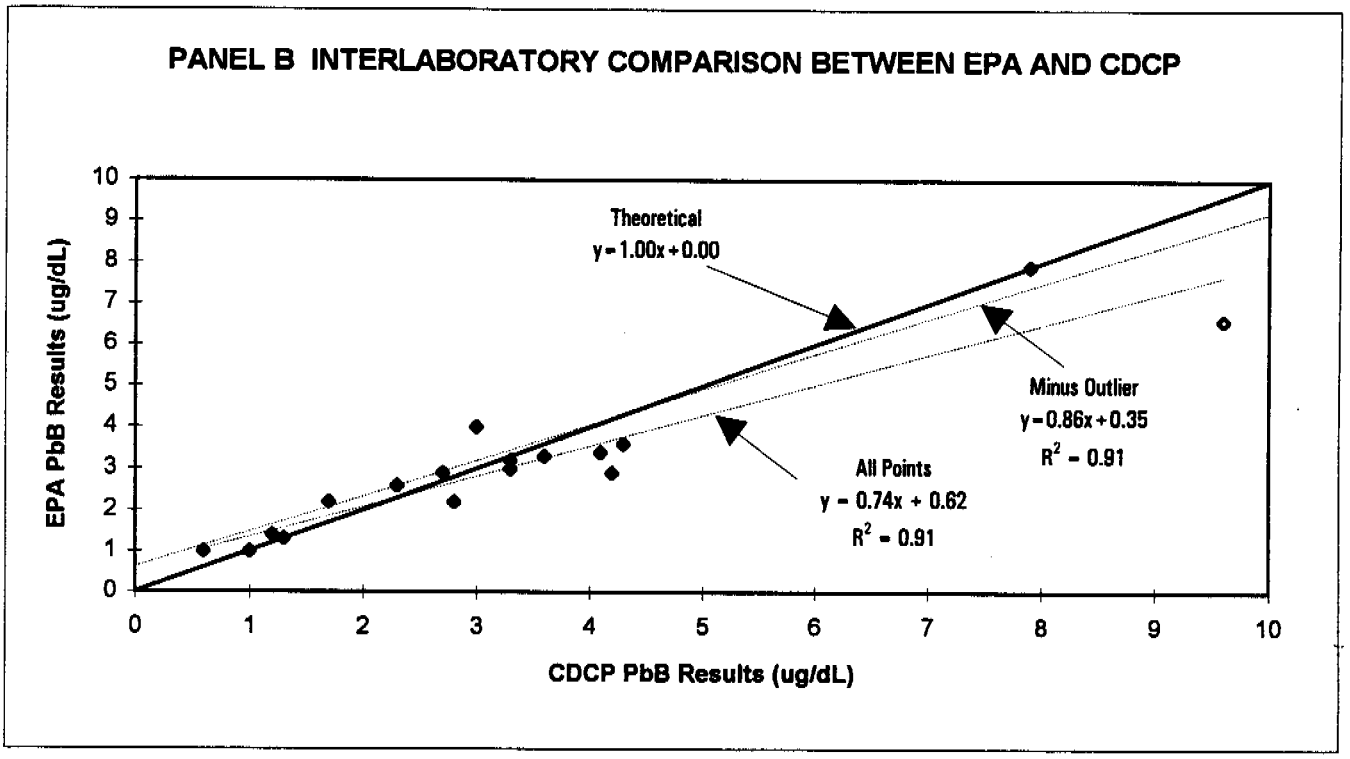




Blind random duplicates submitted at a 5% rate to EPA laboratories to provide a meaure of analytical precision (reproducibility)

FIGURE 3-2 CDCP CHECK SAMPLES





4.0 RESULTS

The following sections provide results based on the group means for each dose group investigated in this study. Appendix A provides detailed data for each individual animal.

4.1 Blood Lead vs Time

Figure 4-1 shows the group mean blood lead values as a function of time during the study. As seen, blood lead values began below quantitation limits (about 1 ug/dL) in all groups, and remained below quantitation limits in control animals (Group 1). In animals given repeated oral doses of lead acetate (Groups 2 and 3) or Butte soil (Groups 7-9), blood levels began to rise within 1-2 days, and tended to plateau by the end of the study (day 15). A similar pattern was observed in animals exposed to lead acetate by intravenous injection (Group 10).

4.2 Dose-Response Patterns

Blood Lead

The measurement endpoint used to quantify the blood lead response was the area under the curve (AUC) for blood lead vs time (days 0-15). This AUC was calculated using the trapezoidal rule to estimate the AUC between each time point that a blood lead value was measured (days 0, 1, 2, 3, 5, 7, 9, 12, and 15), and summing the areas across all time intervals in the study. The detailed data and calculations are presented in Appendix A, and the results are shown graphically in Figure 4-2. Each data point reflects the group mean exposure and group mean response, with the variability in dose and response shown by standard error bars. The figure also shows the best-fit equation through each data set.

As seen, the dose response pattern is non-linear for both the soluble reference material (lead acetate, abbreviated "PbAc"), and for the test soil, with the dose response curves for the test material being clearly lower than the curve for lead acetate.

Tissue Lead

The dose-response data for lead levels in bone, liver and kidney (measured at sacrifice on day 15) are detailed in Appendix A, and are shown graphically in Figures 4-3 through 4-5, respectively. As seen, all of these dose response curves for tissues are fit by linear equations, with the responses (slopes) for the test soil being lower than for lead acetate.

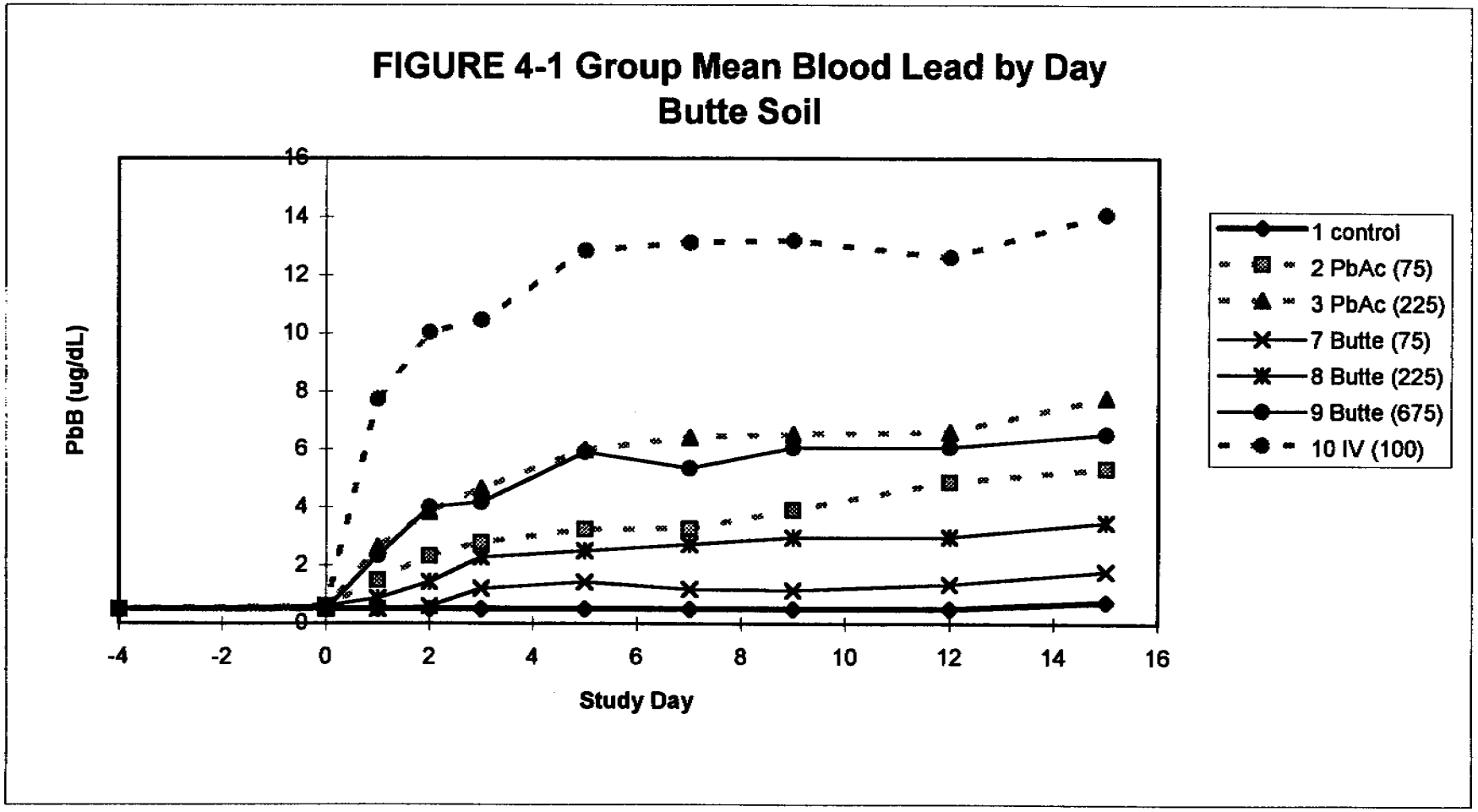
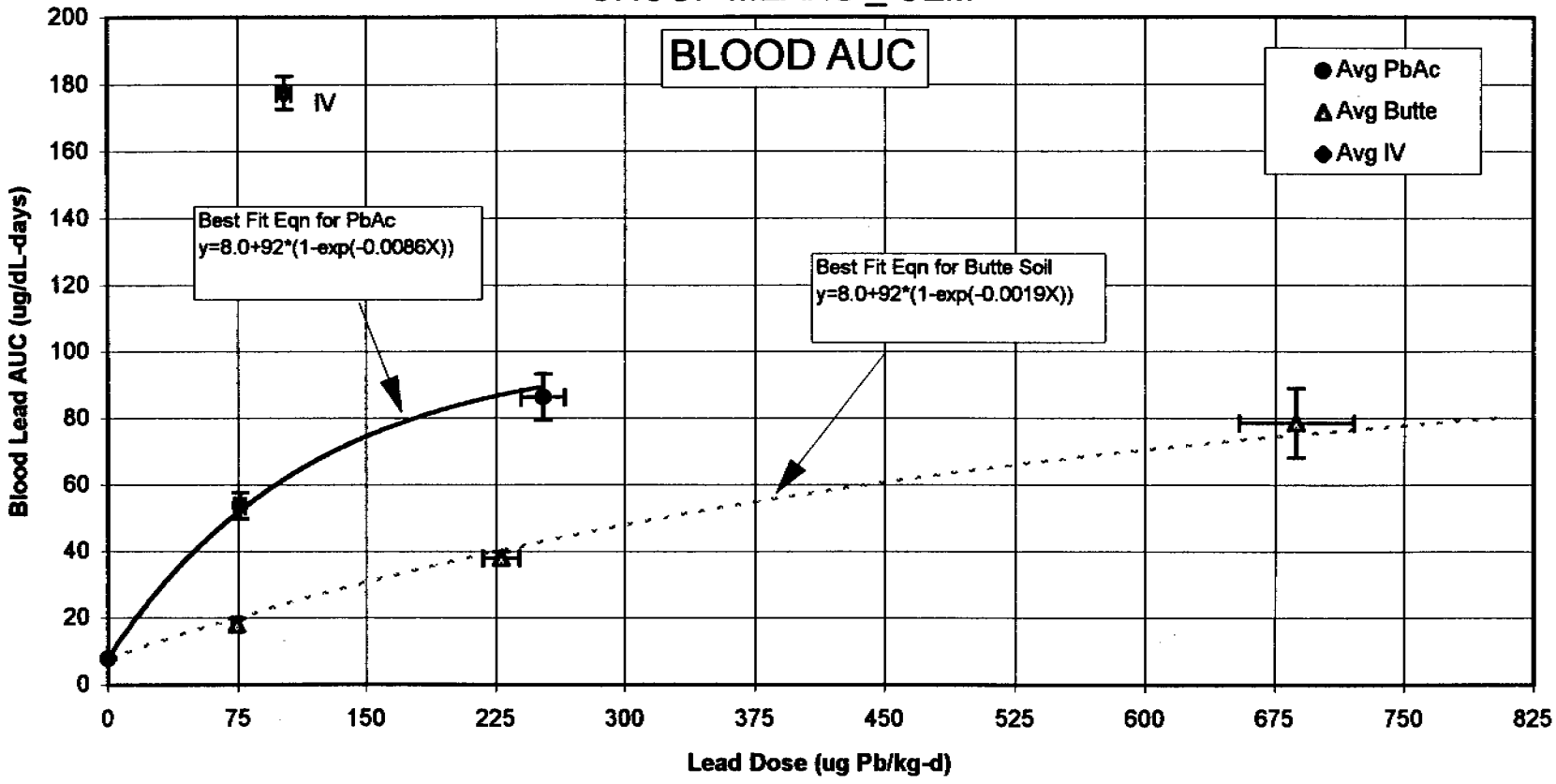


FIGURE 4-1 Group Mean Blood Lead by Day
Butte Soil
PbB (ug/dL)
Study Day
0
2
4
6
8
10
12
14
16
-4
-2
0
2
4
6
8
10
12
14
16
1 control
2 PbAc (75)
3 PbAc (225)
7 Butte (75)
8 Butte (225)
9 Butte (675)
10 IV (100)

FIGURE 4-2 BLOOD LEAD DOSE-RESPONSE
GROUP MEANS ± SEM



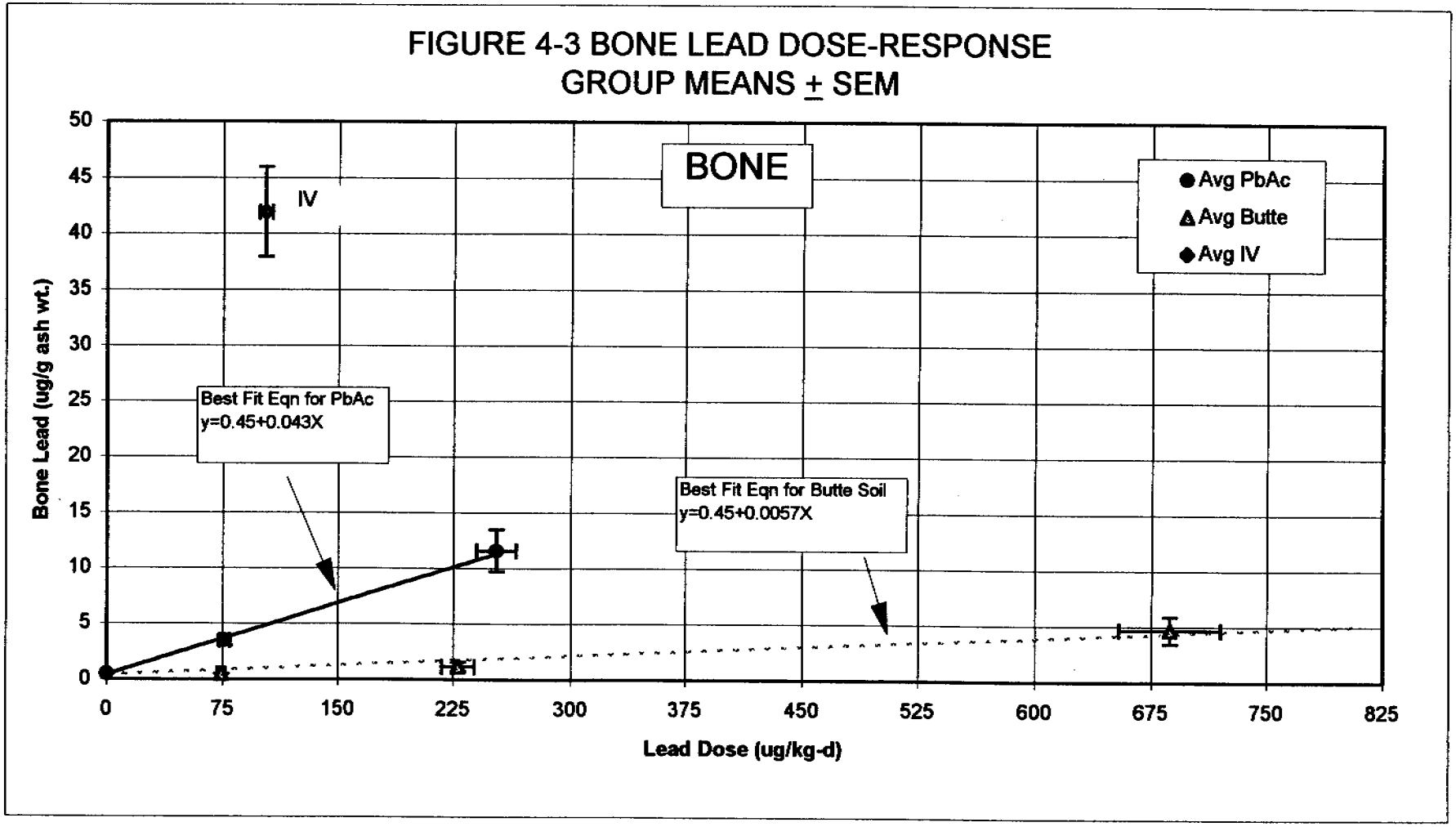


FIGURE 4-3 BONE LEAD DOSE-RESPONSE
GROUP MEANS ± SEM
BONE
Avg PbAc
Avg Butte
Avg IV
IV
Best Fit Eqn for PbAc
y=0.45+0.043X
Best Fit Eqn for Butte Soil
y=0.45+0.0057X
Bone Lead (ug/g ash wt.)
Lead Dose (ug/kg-d)
0
5
10
15
20
25
30
35
40
45
50
0
75
150
225
300
375
450
525
600
675
750
825

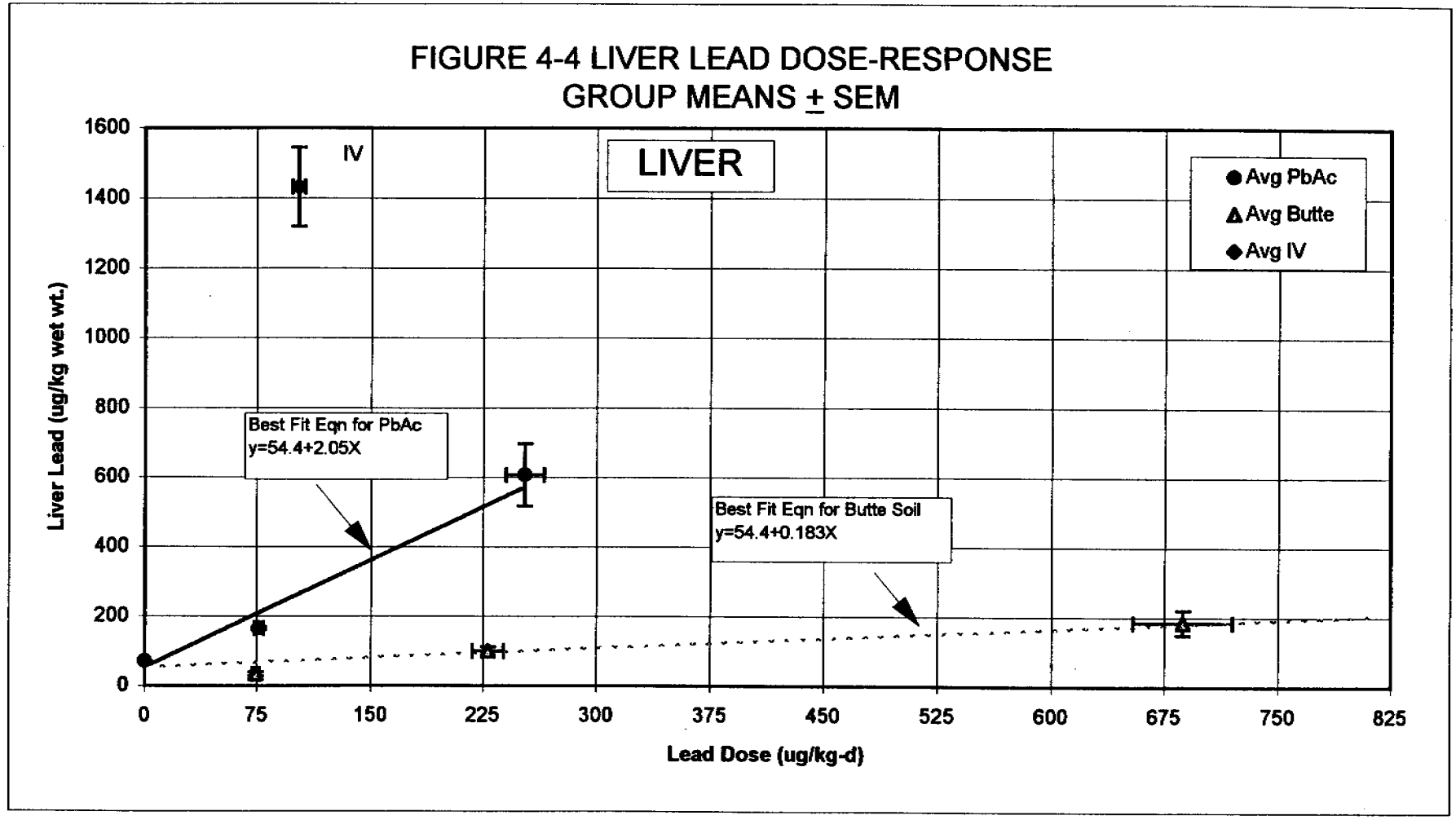
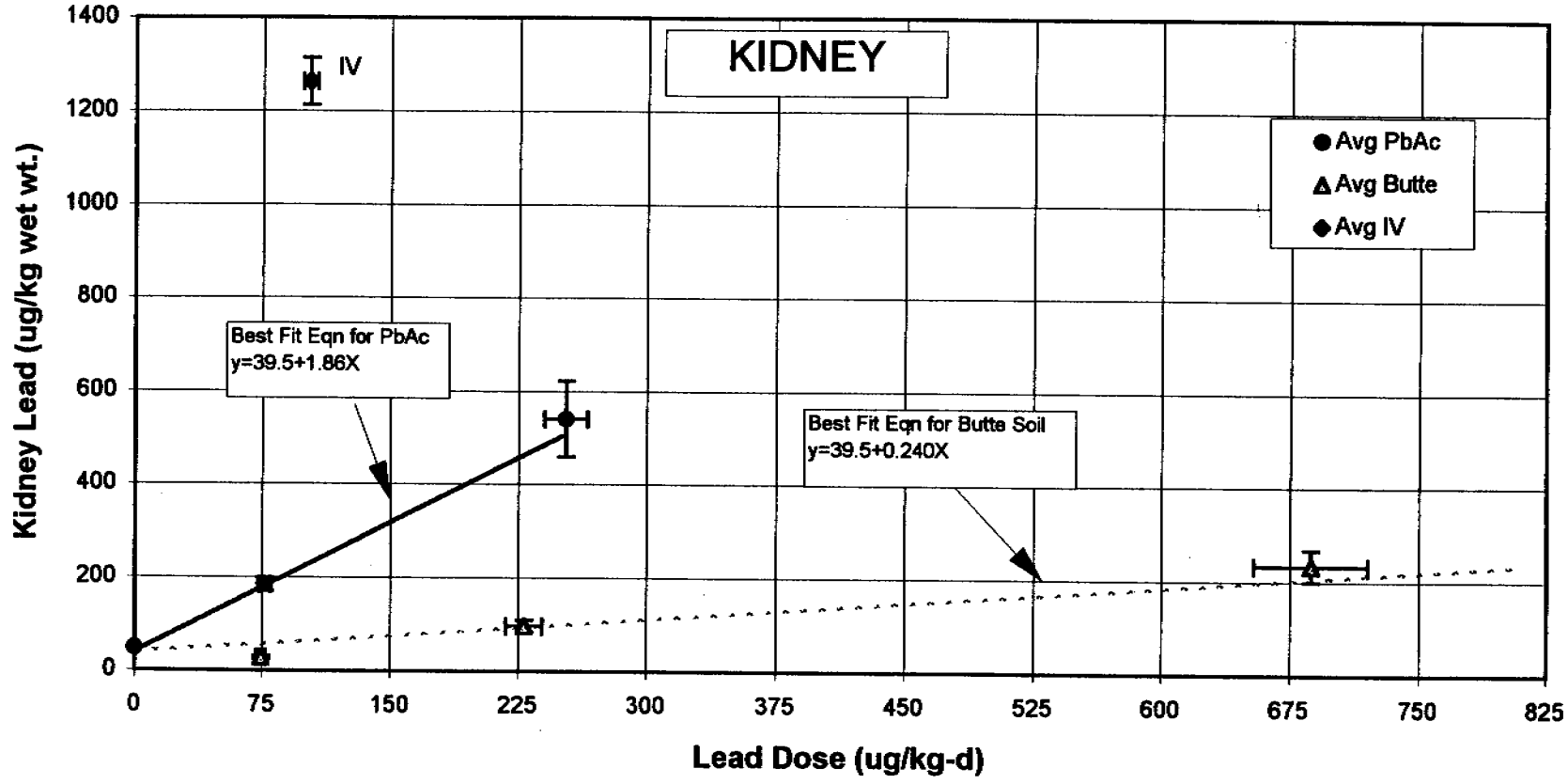


FIGURE 4-4 LIVER LEAD DOSE-RESPONSE
GROUP MEANS ± SEM
LIVER
IV
Avg PbAc
Avg Butte
Avg IV
Best Fit Eqn for PbAc
y=54.4+2.05X
Best Fit Eqn for Butte Soil
y=54.4+0.183X
Liver Lead (ug/kg wet wt.)
Lead Dose (ug/kg-d)
0
200
400
600
800
1000
1200
1400
1600
0
75
150
225
300
375
450
525
600
675
750
825

FIGURE 4-5 KIDNEY LEAD DOSE-RESPONSE
GROUP MEANS ± SEM



4.3 Calculated RBA Values

Relative bioavailability values were calculated for each test material for each measurement endpoint (blood, bone, liver, kidney) using the method described in Section 3.0. The results are shown below:

Measurement Endpoint	RBA Estimate
Blood Lead AUC	0.22
Liver Lead	0.09
Kidney Lead	0.13
Bone Lead	0.13

Recommended RBA Values

As shown above, there are four independent estimates of RBA (based on blood, liver, kidney, and bone), and the values do not agree in all cases. In general, we recommend greatest emphasis be placed on the RBA estimates derived from the blood lead data. There are several reasons for this recommendation, including the following:

1) Blood lead calculations are based on multiple measurements over time, and so are statistically more robust than the single measurements available for tissue concentrations. Further, blood is a homogeneous medium, and is easier to sample than complex tissues such as liver, kidney and bone. Consequently, the AUC endpoint is less susceptible to random measurement errors, and RBA values calculated from AUC data are less uncertain.

2. Blood is the central compartment and one of the first compartments to be affected by absorbed lead. In contrast, uptake of lead into peripheral compartments (liver, kidney, bone) depend on transfer from blood to the tissue, and may be subject to a variety of toxicokinetic factors that could make bioavailability determinations more complicated.

3. The dose-response curve for blood lead is non-linear, similar to the non-linear dose-response curve observed in children (e.g., see Sherlock and Quinn 1986). Thus, the response of this endpoint is known to behave similarly in swine as in children, and it is not known if the same is true for the tissue endpoints.

4. Blood lead is the classical measurement endpoint for evaluating exposure and health effects in humans, and the health effects of lead are believed to be proportional to blood lead levels.

However, data from the tissue endpoints (liver, kidney, bone) also provide valuable information. We consider the plausible range to extend from the RBA based on blood AUC to the mean of the other three tissues (liver, kidney, bone). The preferred range is the interval from the RBA based on blood to the mean of the blood RBA and the tissue mean RBA. Our suggested point estimate is the mid-point of the preferred range. These values are presented below:

RBA Estimate	Value
Plausible range	0.12-0.22
Preferred range	0.17-0.22
Suggested Point Estimate	0.19

4.4 Estimated Absolute Bioavailability in Children

These RBA estimates may be used to help assess lead risk at this site by refining the estimate of absolute bioavailability (ABA) of lead in soil, as follows:

$$ABA_{soil} = ABA_{soluble} \cdot RBA_{soil}$$

Available data indicate that fully soluble forms of lead are about 50% absorbed by a child (USEPA 1991, 1994). Thus, the estimated absolute bioavailability of lead in site soils are calculated as follows:

$$ABA_{Butte} = 50\% \cdot RBA_{Butte}$$

Based on the RBA values shown above, the estimated absolute bioavailability in children is as follows:

ABA Estimate	Value
Plausible range	6% - 11%
Preferred range	8% - 11%
Suggested Point Estimate	10%

4.5 Uncertainty

These absolute bioavailability estimates are appropriate for use in EPA's IEUBK model for this site, although it is clear that there is both variability and uncertainty associated with these estimates. This variability and uncertainty arises from several sources. First, differences in physiological and pharmacokinetic parameters between individual animals leads to variability in response even when exposure is the same. Because of this inter-animal variability in the

responses of different animals to lead exposure, there is mathematical uncertainty in the best fit dose-response curves for both lead acetate and test material. This in turn leads to uncertainty in the calculated values of RBA, because these are derived from the two best-fit equations. Second, there is uncertainty in how to weight the RBA values based on the different endpoints, and how to select a point estimate for RBA that is applicable to typical site-specific exposure levels. Third, there is uncertainty in the extrapolation of measured RBA values in swine to young children. Even though the immature swine is believed to be a useful and meaningful animal model for gastrointestinal absorption in children, it is possible that differences in stomach pH, stomach emptying time, and other physiological parameters may exist and that RBA values in swine may not be precisely equal to values in children. Finally, studies in humans reveal that lead absorption is not constant even within an individual, but varies as a function of many factors (mineral intake, health status, etc.). One factor that may be of special importance is time after the last meal, with the presence of food tending to reduce lead absorption. The values of RBA measured in this study are intended to estimate the maximum uptake that occurs when lead is ingested in the absence of food. Thus, these values may be somewhat conservative for children who ingest lead along with food. The magnitude of this bias is not known, although preliminary studies in swine suggest the factor may be relatively minor.

5.0 REFERENCES

Gibaldi, M. and Perrier, D. 1982. *Pharmacokinetics* (2nd edition) pp 294-297. Marcel Dekker, Inc, NY, NY.

Goodman, A.G., Rall, T.W., Nies, A.S., and Taylor, P. 1990. *The Pharmacological Basis of Therapeutics* (8th ed.) pp. 5-21. Pergamon Press, Inc. Elmsford, NY.

Klaassen, C.D., Amdur, M.O., and Doull, J. (eds). 1996. *Cassarett and Doulls Toxicology: The Basic Science of Poisons*. pp. 190. McGraw-Hill, Inc. NY,NY.

LaVelle, J.M., Poppenga, R.H., Thacker, B.J., Giesy, J.P., Weis, C., Othoudt R, and Vandervoot C. 1991. Bioavailability of Lead in Mining Waste: An Oral Intubation Study in Young Swine. In: The Proceedings of the International Symposium on the Bioavailability and Dietary Uptake of Lead. Science and Technology Letters 3:105-111.

Mushak, P. 1991. Gastro-intestinal Absorption of Lead in Children and Adults: Overview of Biological and Biophysico-chemical Aspects. In: The Proceedings of the International Symposium on the Bioavailability and Dietary Uptake of Lead. Science and Technology Letters 3:87-104.

Sherlock, J.C., and Quinn, M.J. 1986. Relationship Between Blood Lead Concentration and Dietary Intake in Infants: the Glasgow Duplicate Diet Study 1979-1980. Food Additives and Contaminants 3:167-176.

USEPA 1991. Technical Support Document on Lead. United States Environmental Protection Agency, Environmental Criteria and Assessment Office. ECAO-CIN-757.

USEPA 1994. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. United States Environmental Protection Agency, Office of Emergency and Remedial Response. Publication Number 9285.7-15-1. EPA/540/R-93/081.

Weis, C.P. and LaVelle, J.M. 1991. Characteristics to consider when choosing an animal model for the study of lead bioavailability. In: The Proceedings of the International Symposium on the Bioavailability and Dietary Uptake of Lead. Science and Technology Letters 3:113-119.

Weis, C.P., Henningsen, G.M., Poppenga, R.H., and Thacker, B.J. 1993. Pharmacokinetics of Lead in Blood of Immature Swine Following Acute Oral and Intravenous Exposure. The Toxicologist 13(1):175.

Weis, C.P., Poppenga, R.H., Thacker, B.J., Henningsen, G.M., and Curtis, A. 1995. **"Design of Pharmacokinetic and Bioavailability Studies of Lead in an Immature Swine**

Model." **In:** LEAD IN PAINT, SOIL, AND DUST: HEALTH RISKS, EXPOSURE STUDIES, CONTROL MEASURES, MEASUREMENT METHODS, AND QUALITY ASSURANCE. ASTM STP 1226, Michael E. Beard and S. D. Allen Iske, Eds., American Society for Testing and Materials, Philadelphia, 1995.

APPENDIX A

DETAILED DATA AND CALCULATIONS FOR USEPA SWINE BIOAVAILABILITY STUDY PHASE II, EXPERIMENT 6

BUTTE NPL SITE

APPENDIX A

DETAILED DATA SUMMARY

1.0 OVERVIEW

Performance of this study involved collection and reduction of a large number of data items. All of these data items and all of the data reduction steps are contained in a Microsoft Excel spreadsheet named "BUTTE.XLS" that is available upon request from the administrative record. This file is intended to allow detailed review and evaluation by outside parties of all aspects of the study.

The following sections of this Appendix present printouts of selected tables and graphs from the XLS file. These tables and graphs provide a more detailed documentation of the individual animal data and the data reduction steps performed in this study than was presented in the main text. Any additional details of interest to a reader can be found in the XLS spreadsheet.

2.0 RAW DATA AND DATA REDUCTION STEPS

2.1 Body Weights and Dose Calculations

Animals were weighed on day -1 (one day before exposure) and every three days thereafter during the course of the study. Doses of lead for the three days following each weighing were based on the group mean body weight, adjusted by addition of 1 kg to account for the expected weight gain over the interval. After completion of the experiment, body weights were estimated by interpolation for those days when measurements were not collected, and the actual administered doses (ug Pb/kg) were calculated for each day and then averaged across all days. If an animal missed a dose or was given an incorrect dose, the calculation of average dose corrected for these factors. (There were no missed or wrong doses in this study). These data and data reduction steps are shown in Tables A-1 and A-2.

2.2 Blood Lead vs Time

Blood lead values were measured in each animal on days -4, 0, 1, 2, 3, 5, 7, 9, 12, and 15. The raw laboratory data (reported as ug/L of diluted blood) are shown in Table A-3. These data were adjusted as follows: a) non-detects were evaluated by assuming a value equal to one-half the quantitation limit, and b) the concentrations in diluted blood were converted to units of ug/dL in whole blood by dividing by a factor of 1 dL of blood per L of diluted sample. The results are shown in the right-hand column of Table A-3. Figures A-1 to A-3 plot the results for individual animals organized by group and by day. Figure A-4 plots the mean for each dosing group by day.

After adjustment as above, values that were more than a factor of 1.5 above or below the group mean for any given day were "flagged" by computer as potential outliers. These values are shown in Table A-4 by cells that are shaded gray. Each data point identified in this way was reviewed and professional judgement was used to decide if the value should be retained or excluded. In order to avoid inappropriate biases, blood lead outlier designations were restricted to values that were clearly aberrant from a time-course and/or dose-response perspective. Those which were judged to warrant exclusion are shown by a heavy black box around the value. All other flagged values were retained.

Rarely, a value not flagged by the computer was judged to be an outlier that should be excluded. These are shown by unshaded cells surrounded by a heavy black box.

Table A-5 provided a discussion of the rationale used to decide if a blood lead value should be designated as an outlier or not.

2.3 Blood Lead AUC

The area under the blood lead vs time curve for each animal was calculated by finding the area under the curve for each time step using the trapezoidal rule:

$$AUC(d_i \text{ to } d_j) = 0.5*(r_i+r_j)*(d_j-d_i)$$

where:

d = day number
r = response (blood lead value) on day i (r_i) or day j (r_j)

The areas were then summed for each of the time intervals to yield the final AUC for each animal. These calculations are shown in Table A-6. If a blood lead value was missing (either because of problems with sample preparation, or because the measured value was excluded as an outlier), the blood lead value for that day was estimated by linear interpolation.

2.4 Liver, Kidney and Bone Lead Data

At sacrifice (day 15), samples of liver, kidney and bone (femur) were removed and analyzed for lead. The raw data (expressed as ug Pb/L of prepared sample) are summarized in Table A-7. These data were adjusted as follows: a) non-detects were evaluated by assuming a value equal to one-half the quantitation limit, and b) the concentrations in prepared sample were converted to units of concentration in the original biological sample by dividing by the following factors:

Liver:	0.1 kg wet weight/L prepared sample
Kidney:	0.1 kg wet weight/L prepared sample
Bone:	2 gm ashed weight/L prepared sample

The resulting values are shown in the right-hand column of Table A-7.

3.0 CURVE FITTING

Basic Equations

A commercial curve-fitting program (Table Curve-2D™ Version 2.0 for Windows, available from Jandel Scientific) was used to derive best fit equations for each of the individual dose-response data sets derived above. A least squares regression method was used for both linear and non-linear equations. As discussed in the text, three different user-defined equations were fit to each data set:

Linear (LIN): $\text{Response} = a + b \cdot \text{Dose}$

Exponential (EXP): $\text{Response} = a + c \cdot (1-\exp(-d \cdot \text{Dose}))$

Combination (LIN+EXP): $\text{Response} = a + b \cdot \text{Dose} + c \cdot (1-\exp(-d \cdot \text{Dose}))$

Constraints

In the process of finding the best-fits of these equations to the data, the values of the parameters (a, b, c, and d) were constrained as follows:

- Parameter "a" (the intercept, equal to the baseline or control value of the measurement endpoint) was constrained to be non-negative and was forced in all cases to be the same for the reference material (lead acetate) and the test materials. This is because, by definition, all dose-response curves for groups of animals exposed to different materials must arise from the same value at zero dose. In addition, for blood lead data, "a" was constrained to be equal to the mean of the control group $\pm$ 20% (typically 7.5 $\pm$ 1.5 AUC units).

- Parameter "b" (the slope of the linear dose-response line) was constrained to non-negative values, since all of the measurement endpoints evaluated are observed to increase, not decrease, as a function of lead exposure.

- Parameter "c" (the plateau value of the exponential curve) was constrained to be non-negative, and was forced to be the same for the reference material (lead acetate) and the test material. This is because: 1) it is expected on theoretical grounds that the plateau (saturation level) should be the same regardless of the source of lead, and 2) curve-fitting of individual curves tended to yield values of "c" that were close to each other and were not statistically different.

- Parameter "d" (which determines where the "bend" in the exponential equation occurs) was constrained to be greater than 0.0045 for the lead acetate blood lead (AUC) dose-response curve. This constraint was judged to be necessary because the weight of evidence from all studies clearly showed the lead acetate blood lead dose response curve was non-linear and was best fit by an exponential equation, but in some studies there were only two low doses of lead acetate used to define the dose-response curve, and this narrow range data set could sometimes be fit nearly as well by a linear as an exponential curve. The choice of the constraint on "d" was selected to be slightly lower than the observed best-fit value of "d" (0.006) when data from all lead acetate AUC dose-response curves from all of the different studies in this program were used. This approach may tend to underestimate relative bioavailability slightly in some studies (especially at low doses), but use of the information gained from all studies is judged to be more robust than basing fits solely on the data from one study.

In general, one of these models (the linear, the exponential, or the combination) usually yielded a fit (as judged by the value of the adjusted correlation coefficient R^2 and by visual inspection of the fit of the line through the measured data points) that was clearly superior to the others. If two or more models fit the data approximately equally well, then the simplest model (that with the fewest parameters) was selected.

Outlier Identification

During the dose-response curve fitting process, all data were carefully reviewed to identify any anomalous values. Typically, the process used to identify outliers was as follows:

Step 1 Any data points judged to be outliers based on information derived from analysis of data across multiple studies (as opposed to conclusions drawn from within the study) were excluded.

Step 2 The remaining raw data points were fit to the equation judged to be the most likely to be the best fit (linear, exponential, or mixed). Table Curve 2-D was then used to plot the 95% prediction limits around the best fit line. All data points that fell outside the 95% prediction limits were considered to be outliers and were excluded.

Step 3 After excluding these points (if any), a new best-fit was obtained. In some cases, data points originally inside the 95% prediction limits were now outside the limits. However, further iterative cycles of data point exclusion were not performed, and the fit was considered final.

Curve Fit Results

Table A-8 lists the data used to fit these curves, indicating which endpoints were excluded as outliers and why. Table A-9 shows the type of equation selected to fit each data set, and the best fit parameters. The resulting best-fit equations for the data sets are shown in Figures A-5 to A-16. Values excluded as outliers are represented in the figures by the symbol "+".

4.0 RESULTS -- CALCULATED RBA VALUES

The value of RBA for a test substance was calculated for a series of doses using the following procedure:

1. For each dose, calculate the expected response to test material, using the best fit equation through the dose-response data for that material.

2. For each expected response to test material, calculate the dose of lead acetate that is expected to yield an equivalent response. This is done by "inverting" the dose-response curve for lead acetate, solving for the dose that corresponds to a specified response.

3. Calculate RBA at that dose as the ratio of the dose of lead acetate to the dose of test material. For the situation where both curves are linear, the value of RBA is the ratio of the slopes (the "b" parameters). In the case where both curves are exponential and where both curves have the same values for parameters "a" and "c", the value of RBA is equal to the ratio of the "d" parameters.

The results are summarized in Table A-10.

5.0 QUALITY ASSURANCE DATA

A number of steps were taken throughout this study and the other studies in this project to ensure the quality of the results, including 5% duplicates, 5% standards, and a program of interlaboratory comparison. These steps are detailed below.

Duplicates

Duplicate samples were prepared and analyzed for about 5% of all samples generated during the study. Table A-11 lists the first and second values for blood, liver, kidney, and bone. The results are shown in Figure 3-1 in the main text.

Standards

The Centers for Disease Control and Prevention (CDCP) provide a variety of blood lead "check samples" for use in quality assurance programs for blood lead studies. Each time a group of

blood samples was prepared and sent to the laboratory for analysis, several CDCP check samples of different concentrations were included. Table A-12 lists the concentrations reported by the laboratory compared to the nominal concentrations indicated by CDCP for the samples submitted during this study, and the results are plotted in Figure 3-2 (Panel A) in the main text.

Interlaboratory Comparison

An interlaboratory comparison of blood lead analytical results was performed by sending a set of 15 randomly selected whole blood samples from this study to CDCP for independent analysis. The data are presented in Table A-13, and the results are plotted in Figure 3-2 (Panel B) in the main text.

DISK INSTRUCTIONS

Enclosed is a disk entitled "BUTTE.EXE". This disk contains all of the data items and all of the data reduction steps for the Butte site in a Microsoft Excel spreadsheet named "BUTTE.XLS". This file is intended to allow detailed review and evaluation by outside parties of all aspects of the study. In order to conserve space and help guard against accidental changes in the spreadsheet, all of the formulas and links present in the original spreadsheet used by EPA have been "frozen". Thus, the values shown in the attached file represent the final values employed by EPA. Due to the size of the file (approximately 2 MB), it has been provided as a self-extracting zipped file. To extract the file from the enclosed disk to a location on your hard drive, the following steps should be taken:

1) Go to the DOS Prompt
2) Change directory to desired destination directory (e.g., C:\data)
3) Place the source disk in the appropriate drive (e.g., A:)
4) At the DOS prompt (C:\data>) type "A:\BUTTE" and press enter. This will cause the BUTTE.XLS file to extract from your source disk (A:) to your destination directory (C:\data).
5) Open Microsoft Excel to view the unzipped file. Note that even though the formulas have been frozen, the file remains quite large, so it is recommended that the user have a minimum of 8 MB of RAM to facilitate use of this spreadsheet.

TABLE A-1 BODY WEIGHTS AND ADMINISTERED DOSES, BY DAY*

Body weights were measured on days -1, 2, 5, 8, 11, 14. Weights for other days are estimated, based on linear interpolation between measured values.

Group	ID #	Day -1		Day 0		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14		Day 15	
		BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day	BW (kg)	ug Pb per day
1	614	10.8	0	11.0	0	11.4	0	11.8	0	12.2	0	12.6	0	13	0	13.5	0	14.0	0	14.5	0	15.1	0	15.8	0	16.2	0	16.8	0	17.5	0	18.1	0	18.7	0
1	638	9.5	0	10.0	0	10.5	0	11	0	11.4	0	11.8	0	12.3	0	13.2	0	14.0	0	14.9	0	14.8	0	15.0	0	15	0	15.5	0	15.9	0	16.4	0	16.9	0
2	613	11.7	0	12.2	911	12.6	911	13.1	911	13.4	992	13.8	992	14.1	992	14.6	1062	15.2	1062	15.7	1062	16.1	1182	16.6	1182	17	1182	17.7	1274	18.4	1274	19.1	1274	19.8	0
2	624	10.6	0	11.0	911	11.5	911	11.9	911	12.2	992	12.5	992	12.9	992	13.2	1062	13.5	1062	13.9	1062	14.3	1182	14.8	1182	15.2	1182	15.8	1274	16.5	1274	16.9	1274	17.5	0
2	630	11.5	0	11.8	911	12.0	911	12.3	911	12.6	992	12.8	992	13.1	992	13.7	1062	14.3	1062	14.8	1062	15.3	1182	15.8	1182	16	1182	16.5	1274	17.1	1274	17.6	1274	18.1	0
2	639	12.2	0	12.6	911	13.1	911	13.5	911	13.8	992	14.1	992	14.4	992	15.1	1062	15.8	1062	16.5	1062	16.8	1182	17.1	1182	17.4	1182	18.0	1274	18.5	1274	19.1	1274	19.7	0
2	641	9.7	0	9.9	911	10.1	911	10.3	911	10.7	992	11.0	992	11.4	992	11.9	1062	12.3	1062	12.8	1062	13.3	1182	13.8	1182	14.3	1182	15.0	1274	15.7	1274	16.4	1274	17.1	0
3	616	9.6	0	9.7	2732	9.8	2732	9.9	2732	9.9	2975	9.8	2975	9.7	2975	10.0	3186	10.2	3186	10.5	3186	10.9	3548	11.3	3548	11.7	3548	12.4	3821	13.0	3821	13.7	3821	14.4	0
3	644	9.6	0	10.0	2732	10.5	2732	10.9	2732	11.1	2975	11.4	2975	11.6	2975	12.1	3186	12.6	3186	13.1	3186	13.6	3548	14.1	3548	14.6	3548	15.3	3821	15.9	3821	16.6	3821	17.3	0
3	651	10.5	0	11.1	2732	11.8	2732	12.4	2732	12.7	2975	13.0	2975	13.3	2975	13.2	3186	13.2	3186	13.1	3186	14.2	3548	15.3	3548	16.4	3548	17.1	3821	17.8	3821	18.5	3821	19.2	0
3	653	10.1	0	10.8	2732	11.1	2732	11.8	2732	12.1	2975	12.7	2975	13.2	2975	13.1	3186	12.9	3186	12.8	3186	14.0	3548	15.1	3548	16.3	3548	16.9	3821	17.4	3821	18	3821	18.6	0
3	654	10.2	0	10.5	2732	10.9	2732	11.2	2732	11.5	2975	11.9	2975	12.2	2975	12.8	3186	13.4	3186	14	3186	14.5	3548	15.0	3548	15.5	3548	16.1	3821	16.7	3821	17.3	3821	17.9	0
7	610	12.4	0	12.8	867	13.1	867	13.5	867	13.7	963	13.9	963	14.1	963	14.6	1037	15.0	1037	15.5	1037	15.9	1143	16.2	1143	16.6	1143	17.0	1248	17.5	1248	17.9	1248	18.3	0
7	611	10.3	0	10.5	867	10.7	867	10.9	867	11.3	963	11.8	963	12.2	963	12.4	1037	12.7	1037	12.9	1037	13.2	1143	13.5	1143	13.8	1143	14.4	1248	14.9	1248	15.5	1248	16.1	0
7	617	11.4	0	11.8	867	12.1	867	12.5	867	12.8	963	13.2	963	13.6	963	14.1	1037	14.6	1037	15.1	1037	15.6	1143	16.1	1143	16.6	1143	17.1	1248	17.6	1248	18.1	1248	18.6	0
7	637	10.7	0	11.2	867	11.6	867	12.1	867	12.4	963	12.7	963	13	963	13.5	1037	13.9	1037	14.4	1037	14.4	1143	14.3	1143	14.3	1143	15.3	1248	16.4	1248	17.4	1248	18.4	0
7	643	11.4	0	11.8	867	12.1	867	12.5	867	12.8	963	13.3	963	13.7	963	14.2	1037	14.7	1037	15.2	1037	15.8	1143	16.3	1143	16.9	1143	17.5	1248	18.2	1248	18.8	1248	19.4	0
8	601	12	0	12.5	2772	12.9	2772	13.4	2772	13.8	3008	14.1	3008	14.5	3006	15.2	3290	15.9	3290	16.6	3290	17.0	3650	17.4	3650	17.8	3650	18.5	3974	19.1	3974	19.8	3974	20.5	0
8	609	9.9	0	10.2	2772	10.6	2772	10.9	2772	11.4	3008	11.9	3006	12.4	3006	12.8	3290	13.4	3290	13.9	3290	14.4	3650	15.0	3650	15.5	3650	16.0	3974	16.5	3974	17	3974	17.5	0
8	618	12.3	0	12.6	2772	13.0	2772	13.3	2772	13.7	3008	14.2	3006	14.6	3006	15.1	3290	15.5	3290	16	3290	16.5	3650	17.0	3650	17.5	3650	18.1	3974	18.7	3974	19.3	3974	19.9	0
8	621	12.4	0	12.9	2772	13.2	2772	13.6	2772	14.0	3008	14.4	3006	14.8	3006	15.2	3290	15.7	3290	16.1	3290	16.7	3650	17.2	3650	17.8	3650	18.5	3974	19.1	3974	19.8	3974	20.5	0
8	635	10	0	10.2	2772	10.4	2772	10.6	2772	11.0	3008	11.4	3006	11.8	3006	12.4	3290	12.9	3290	13.5	3290	13.9	3650	14.3	3650	14.7	3650	15.4	3974	16.0	3974	16.7	3974	17.4	0
9	620	10.7	0	11.0	7803	11.4	7803	11.7	7803	11.9	8667	12.0	8667	12.2	8667	12.5	9329	12.9	9329	13.2	9329	13.5	10287	13.9	10287	14.1	10287	14.8	11232	15.5	11232	16.2	11232	16.9	0
9	627	11.3	0	11.8	7803	12.3	7803	12.9	7803	13.2	8667	13.5	8667	13.9	8667	14.5	9329	15.0	9329	15.8	9329	16.0	10287	16.5	10287	16.9	10287	17.4	11232	18.0	11232	18.5	11232	19.0	0
9	634	8.3	0	8.6	7803	9.2	7803	9.7	7803	10.1	8667	10.4	8667	10.8	8667	11.4	9329	12.0	9329	12.6	9329	13.2	10287	13.9	10287	14.4	10287	14.9	11232	15.4	11232	15.9	11232	16.4	0
9	648	10.2	0	10.6	7803	11.1	7803	11.5	7803	11.9	8667	12.2	8667	12.5	8667	12.9	9329	13.3	9329	13.7	9329	14.2	10287	14.8	10287	15.3	10287	16.1	11232	16.9	11232	17.7	11232	18.5	0
9	655	12.3	0	12.7	7803	13.1	7803	13.5	7803	13.9	8667	14.3	8667	14.7	8667	15.2	9329	15.6	9329	16.1	9329	16.6	10287	17.0	10287	17.5	10287	18.1	11232	18.8	11232	19.2	11232	19.8	0
10	604	9.6	0	10.0	1141	10.3	1141	10.7	1141	11.1	1233	11.4	1233	11.8	1233	12.3	1334	12.9	1334	13.4	1334	13.9	1481	14.5	1481	15	1481	15.5	1626	16.1	1626	16.6	1626	17.1	0
10	606	10.1	0	10.5	1141	10.9	1141	11.3	1141	11.6	1233	11.9	1233	12.2	1233	12.7	1334	13.1	1334	13.6	1334	14.1	1481	14.7	1481	15.2	1481	15.9	1626	16.7	1626	17.4	1626	18.1	0
10	607	12.4	0	12.7	1141	13.1	1141	13.4	1141	13.9	1233	14.4	1233	14.9	1233	15.4	1334	15.9	1334	16.4	1334	16.9	1481	17.4	1481	17.9	1481	18.5	1626	19.2	1626	19.8	1626	20.4	0
10	612	9.8	0	10.0	1141	10.3	1141	10.5	1141	11.0	1233	11.4	1233	11.9	1233	12.4	1334	12.9	1334	13.4	1334	13.8	1481	14.3	1481	14.8	1481	15.4	1626	15.9	1626	16.5	1626	17.1	0
10	625	11.5	0	11.8	1141	12.0	1141	12.3	1141	12.4	1233	12.5	1233	12.6	1233	13.1	1334	13.7	1334	14.2	1334	14.8	1481	15.5	1481	16.1	1481	16.7	1626	17.2	1626	17.8	1626	18.4	0
10	632	10.1	0	10.5	1141	10.8	1141	11.2	1141	11.4	1233	11.7	1233	11.9	1233	12.3	1334	12.8	1334	13.2	1334	13.7	1481	14.3	1481	14.8	1481	15.5	1626	16.2	1626	16.9	1626	17.6	0
10	642	11	0	11.3	1141	11.5	1141	11.8	1141	12.3	1233	12.7	1233	13.2	1233	14.0	1334	14.7	1334	15.5	1334	15.8	1481	16.2	1481	16.6	1481	17.3	1626	18.1	1626	18.8	1626	19.5	0
10	648	8.8	0	9.0	1141	9.2	1141	9.4	1141	9.7	1233	9.9	1233	10.2	1233	10.4	1334	10.8	1334	10.8	1334	11.1	1481	11.4	1481	11.7	1481	12.3	1626	12.9	1626	13.5	1626	14.1	0

* Groups 4, 5, & 6 not shown (data for samples from a different site)

TABLE A-2
Body Weight Adjusted Doses
(Dose for Day/BW for Day)

Group	ID #	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Avg Dose	Target Dose	% Target	Avg %
1	614	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0		
1	638	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0		
2	613	74.8	72.1	69.5	73.8	72.0	70.3	72.6	70.0	67.6	73.3	71.3	69.5	71.9	69.2	66.7	71.0	75	95	
2	624	82.5	79.4	76.5	81.3	79.3	77.5	80.7	78.5	76.4	82.5	80.0	77.8	80.8	78.0	75.4	79.1	75	105	
2	630	77.4	75.7	74.0	78.9	77.3	75.7	77.5	74.3	71.3	77.4	75.6	73.9	77.0	74.6	72.4	75.5	75	101	
2	639	72.1	69.7	67.4	71.6	70.3	68.9	70.3	67.2	64.4	70.4	69.1	67.9	70.9	68.7	66.7	69.1	75	92	
2	641	92.0	90.1	88.4	93.0	89.9	87.0	89.5	86.1	83.0	88.9	85.7	82.7	84.9	81.1	77.7	86.6	75	116	102
3	616	281.6	278.7	275.9	302.5	304.6	306.6	319.7	311.3	303.4	325.3	313.8	303.1	308.9	293.1	278.9	300.5	225	134	
3	644	272.2	261.0	250.6	267.2	261.7	256.4	263.3	252.9	243.2	260.7	251.5	242.9	250.3	239.8	230.2	253.6	225	113	
3	651	245.3	232.1	220.3	234.2	228.8	223.6	240.8	242.0	243.2	249.7	231.8	216.2	223.4	214.6	206.5	230.2	225	102	
3	653	257.7	246.1	235.5	245.2	234.8	225.3	243.8	246.3	248.9	253.9	234.3	217.5	226.5	219.1	212.3	236.5	225	105	
3	654	259.3	251.4	243.9	257.9	250.7	243.8	248.9	237.8	227.6	244.6	236.4	228.8	237.3	228.8	220.8	241.2	225	107	112
7	610	67.9	66.0	64.2	70.3	69.3	68.3	71.2	68.9	66.9	72.0	70.4	68.9	73.3	71.5	69.7	69.2	75	92	
7	611	82.6	81.0	79.5	85.0	81.8	78.9	83.4	81.8	80.3	86.6	84.7	82.8	86.9	83.6	80.5	82.6	75	110	
7	617	73.7	71.5	69.4	74.8	72.8	70.8	73.5	71.0	68.6	73.3	71.0	68.9	73.0	70.9	69.0	71.5	75	95	
7	637	77.6	74.5	71.7	77.7	75.8	74.1	77.0	74.4	72.0	79.6	79.7	79.9	81.4	76.3	71.7	76.2	75	102	
7	643	73.7	71.5	69.4	74.7	72.4	70.3	73.0	70.5	68.2	72.5	70.0	67.6	71.2	68.7	66.4	70.7	75	94	99
8	601	222.4	214.3	206.9	218.4	212.7	207.3	216.4	206.9	198.2	214.7	209.7	205.0	215.2	207.7	200.7	210.4	225	94	
8	609	270.9	262.3	254.3	263.7	252.6	242.4	255.0	245.5	236.7	252.9	243.8	235.5	248.3	240.8	233.7	249.2	225	111	
8	618	219.4	213.8	208.4	218.9	212.2	205.9	216.3	211.8	205.6	221.2	214.7	208.5	219.5	212.5	205.9	213.1	225	95	
8	621	216.6	210.0	203.8	214.7	208.8	203.1	215.9	210.0	204.3	219.0	211.8	205.0	215.2	207.7	200.7	209.8	225	93	
8	635	271.8	266.5	261.5	273.3	263.7	254.7	266.0	254.3	243.7	262.6	255.2	248.3	258.6	247.8	237.9	257.7	225	115	101
9	620	707.2	686.5	666.9	730.4	720.2	710.4	744.3	725.0	706.7	762.0	745.4	729.6	758.9	724.6	693.3	720.8	675	107	
9	627	661.3	634.4	609.6	658.3	640.4	623.5	644.8	620.5	598.0	641.6	624.7	608.7	644.3	625.2	607.1	629.5	675	93	
9	634	890.1	845.1	804.4	861.0	830.7	802.5	818.3	777.4	740.4	779.3	745.4	714.4	753.8	729.4	706.4	788.6	675	117	
9	646	733.8	705.1	678.5	732.4	712.4	693.4	723.1	701.4	680.9	722.7	696.6	672.4	697.6	664.6	634.6	696.6	675	103	
9	655	614.4	595.6	578.0	623.5	606.1	589.6	615.1	596.7	579.4	620.9	603.9	587.8	621.7	602.8	585.0	601.4	675	89	102
10	604	114.5	110.4	106.7	111.4	107.8	104.4	108.1	103.7	99.5	106.3	102.4	98.8	104.7	101.2	98.0	105.2	100	105	
10	606	108.7	104.7	101.0	106.3	103.6	101.0	105.3	101.6	98.1	104.8	101.0	97.5	102.1	97.6	93.5	101.8	100	102	
10	607	89.6	87.3	85.2	88.7	85.6	82.7	86.6	83.9	81.3	87.6	85.1	82.8	87.7	84.8	82.1	85.4	100	85	
10	612	113.7	111.2	108.7	112.4	107.8	103.8	107.6	103.4	99.5	106.8	103.3	100.1	105.8	102.1	98.6	105.6	100	106	
10	625	97.0	94.8	92.8	99.4	98.6	97.8	101.6	97.6	93.9	99.9	95.8	92.0	97.6	94.4	91.4	96.3	100	96	
10	632	109.0	105.3	101.9	107.8	105.6	103.6	108.1	104.5	101.0	107.9	103.8	100.1	104.9	100.4	96.2	104.0	100	104	
10	642	101.3	99.0	96.7	100.5	96.8	93.4	95.5	90.5	86.0	93.4	91.2	89.2	93.8	90.0	86.5	93.6	100	94	
10	648	126.8	124.0	121.4	127.5	124.1	120.8	126.2	125.8	123.5	133.4	129.9	126.6	132.2	126.1	120.5	126.1	100	126	102

* Groups 4, 5, & 6 not shown (data for samples from a different site)

TABLE A - 3 RAW AND ADJUSTED BLOOD LEAD DATA

PHASE II EXPERIMENT 6 (Data not shown for groups 4, 5, & 6)

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value (ug/dL)[a]	Notes
614	8-960124	1	control	0	<	1	-4	pig41.dat	BLOOD	0.5	
638	8-960163	1	control	0	<	1	-4	pig41.dat	BLOOD	0.5	
613	8-960167	2	PbAc	75	<	1	-4	pig41.dat	BLOOD	0.5	
624	8-960153	2	PbAc	75	<	1	-4	pig41.dat	BLOOD	0.5	
630	8-960155	2	PbAc	75	<	1	-4	pig41.dat	BLOOD	0.5	
639	8-960141	2	PbAc	75	<	1	-4	pig41.dat	BLOOD	0.5	
641	8-960158	2	PbAc	75	<	1	-4	pig41.dat	BLOOD	0.5	
616	8-960132	3	PbAc	225	<	1	-4	pig41.dat	BLOOD	0.5	
644	8-960120	3	PbAc	225	<	1	-4	pig41.dat	BLOOD	0.5	
651	8-960140	3	PbAc	225	<	1	-4	pig41.dat	BLOOD	0.5	
653	8-960172	3	PbAc	225	<	1	-4	pig41.dat	BLOOD	0.5	
654	8-960129	3	PbAc	225	<	1	-4	pig41.dat	BLOOD	0.5	
610	8-960130	7	Butte	75	<	1	-4	pig41.dat	BLOOD	0.5	
611	8-960142	7	Butte	75	<	1	-4	pig41.dat	BLOOD	0.5	
617	8-960174	7	Butte	75	<	1	-4	pig41.dat	BLOOD	0.5	
637	8-960137	7	Butte	75	<	1	-4	pig41.dat	BLOOD	0.5	
643	8-960156	7	Butte	75	<	1	-4	pig41.dat	BLOOD	0.5	
601	8-960159	8	Butte	225	<	1	-4	pig41.dat	BLOOD	0.5	
609	8-960127	8	Butte	225	<	1	-4	pig41.dat	BLOOD	0.5	
618	8-960166	8	Butte	225	<	1	-4	pig41.dat	BLOOD	0.5	
621	8-960144	8	Butte	225	<	1	-4	pig41.dat	BLOOD	0.5	
635	8-960149	8	Butte	225	<	1	-4	pig41.dat	BLOOD	0.5	
620	8-960146	9	Butte	675	<	1	-4	pig41.dat	BLOOD	0.5	
627	8-960165	9	Butte	675	<	1	-4	pig41.dat	BLOOD	0.5	
634	8-960170	9	Butte	675	<	1	-4	pig41.dat	BLOOD	0.5	
646	8-960169	9	Butte	675	<	1	-4	pig41.dat	BLOOD	0.5	
655	8-960168	9	Butte	675	<	1	-4	pig41.dat	BLOOD	0.5	
604	8-960164	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
606	8-960122	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
607	8-960150	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
612	8-960125	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
625	8-960160	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
632	8-960173	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
642	8-960151	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
648	8-960126	10	IV	100	<	1	-4	pig41.dat	BLOOD	0.5	
614	8-960214	1	control	0	<	1	0	pig41.dat	BLOOD	0.5	
638	8-960229	1	control	0	<	1	0	pig41.dat	BLOOD	0.5	
613	8-960181	2	PbAc	75	<	1	0	pig41.dat	BLOOD	0.5	
624	8-960213	2	PbAc	75		1	0	pig41.dat	BLOOD	1	
630	8-960179	2	PbAc	75	<	1	0	pig41.dat	BLOOD	0.5	
639	8-960222	2	PbAc	75	<	1	0	pig41.dat	BLOOD	0.5	
641	8-960219	2	PbAc	75	<	1	0	pig41.dat	BLOOD	0.5	
616	8-960193	3	PbAc	225	<	1	0	pig41.dat	BLOOD	0.5	
644	8-960205	3	PbAc	225	<	1	0	pig41.dat	BLOOD	0.5	
651	8-960189	3	PbAc	225	<	1	0	pig41.dat	BLOOD	0.5	
653	8-960226	3	PbAc	225	<	1	0	pig41.dat	BLOOD	0.5	
654	8-960224	3	PbAc	225	<	1	0	pig41.dat	BLOOD	0.5	
610	8-960207	7	Butte	75	<	1	0	pig41.dat	BLOOD	0.5	
611	8-960177	7	Butte	75	<	1	0	pig41.dat	BLOOD	0.5	
617	8-960175	7	Butte	75	<	1	0	pig41.dat	BLOOD	0.5	
637	8-960187	7	Butte	75	<	1	0	pig41.dat	BLOOD	0.5	
643	8-960223	7	Butte	75	<	1	0	pig41.dat	BLOOD	0.5	
601	8-960215	8	Butte	225	<	1	0	pig41.dat	BLOOD	0.5	
609	8-960192	8	Butte	225	<	1	0	pig41.dat	BLOOD	0.5	
618	8-960211	8	Butte	225		1.1	0	pig41.dat	BLOOD	1.1	
621	8-960176	8	Butte	225	<	1	0	pig41.dat	BLOOD	0.5	
635	8-960197	8	Butte	225	<	1	0	pig41.dat	BLOOD	0.5	
620	8-960178	9	Butte	675	<	1	0	pig41.dat	BLOOD	0.5	
627	8-960212	9	Butte	675	<	1	0	pig41.dat	BLOOD	0.5	
634	8-960194	9	Butte	675	<	1	0	pig41.dat	BLOOD	0.5	
646	8-960180	9	Butte	675	<	1	0	pig41.dat	BLOOD	0.5	
655	8-960186	9	Butte	675	<	1	0	pig41.dat	BLOOD	0.5	
604	8-960225	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
606	8-960228	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
607	8-960220	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
612	8-960198	10	IV	100		1.1	0	pig41.dat	BLOOD	1.1	
625	8-960208	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
632	8-960182	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
642	8-960191	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
648	8-960199	10	IV	100	<	1	0	pig41.dat	BLOOD	0.5	
614	8-960277	1	control	0	<	1	1	pig41.dat	BLOOD	0.5	
638	8-960258	1	control	0	<	1	1	pig41.dat	BLOOD	0.5	
613	8-960268	2	PbAc	75		1.2	1	pig41.dat	BLOOD	1.2	
624	8-960246	2	PbAc	75		2.4	1	pig41.dat	BLOOD	2.4	
630	8-960283	2	PbAc	75		1.2	1	pig41.dat	BLOOD	1.2	
639	8-960251	2	PbAc	75		2.1	1	pig41.dat	BLOOD	2.1	
641	8-960242	2	PbAc	75	<	1	1	pig41.dat	BLOOD	0.5	
616	8-960233	3	PbAc	225		1.7	1	pig41.dat	BLOOD	1.7	
644	8-960262	3	PbAc	225		2.8	1	pig41.dat	BLOOD	2.8	
651	8-960278	3	PbAc	225		1.9	1	pig41.dat	BLOOD	1.9	
653	8-960261	3	PbAc	225		3.8	1	pig41.dat	BLOOD	3.8	
654	8-960248	3	PbAc	225		3	1	pig41.dat	BLOOD	3	
610	8-960247	7	Butte	75	<	1	1	pig41.dat	BLOOD	0.5	
611	8-960250	7	Butte	75	<	1	1	pig41.dat	BLOOD	0.5	
617	8-960271	7	Butte	75	<	1	1	pig41.dat	BLOOD	0.5	
637	8-960244	7	Butte	75	<	1	1	pig41.dat	BLOOD	0.5	
643	8-960276	7	Butte	75	<	1	1	pig41.dat	BLOOD	0.5	
601	8-960259	8	Butte	225		1.4	1	pig41.dat	BLOOD	1.4	

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value (ug/dL)[a]	Notes
609	8-960265	8	Butte	225	<	1	1	pig41.dat	BLOOD	0.5	
618	8-960284	8	Butte	225		1.5	1	pig41.dat	BLOOD	1.5	
621	8-960234	8	Butte	225	<	1	1	pig41.dat	BLOOD	0.5	
635	8-960256	8	Butte	225	<	1	1	pig41.dat	BLOOD	0.5	
620	8-960279	9	Butte	675		3.3	1	pig41.dat	BLOOD	3.3	
627	8-960264	9	Butte	675		3.6	1	pig41.dat	BLOOD	3.6	
634	8-960257	9	Butte	675		1.7	1	pig41.dat	BLOOD	1.7	
646	8-960236	9	Butte	675		1.4	1	pig41.dat	BLOOD	1.4	
655	8-960263	9	Butte	675		1.7	1	pig41.dat	BLOOD	1.7	
604	8-960249	10	IV	100		6.6	1	pig41.dat	BLOOD	6.6	
606	8-960267	10	IV	100		7.5	1	pig41.dat	BLOOD	7.5	
607	8-960274	10	IV	100		8.2	1	pig41.dat	BLOOD	8.2	
612	8-960273	10	IV	100		9.2	1	pig41.dat	BLOOD	9.2	
625	8-960232	10	IV	100		8	1	pig41.dat	BLOOD	8	
632	8-960239	10	IV	100		6.6	1	pig41.dat	BLOOD	6.6	
642	8-960243	10	IV	100		7.3	1	pig41.dat	BLOOD	7.3	
648	8-960266	10	IV	100		8.4	1	pig41.dat	BLOOD	8.4	
614	8-960308	1	control	0	<	1	2	pig44.dat	BLOOD	0.5	
638	8-960329	1	control	0	<	1	2	pig44.dat	BLOOD	0.5	
613	8-960298	2	PbAc	75		3.4	2	pig44.dat	BLOOD	3.4	
624	8-960323	2	PbAc	75		2.9	2	pig44.dat	BLOOD	2.9	
630	8-960300	2	PbAc	75		1.2	2	pig44.dat	BLOOD	1.2	
639	8-960291	2	PbAc	75		2.6	2	pig44.dat	BLOOD	2.6	
641	8-960332	2	PbAc	75		1.5	2	pig44.dat	BLOOD	1.5	
616	8-960293	3	PbAc	225		3	2	pig44.dat	BLOOD	3	
644	8-960312	3	PbAc	225		4.3	2	pig44.dat	BLOOD	4.3	
651	8-960311	3	PbAc	225		2.1	2	pig44.dat	BLOOD	2.1	
653	8-960327	3	PbAc	225		7.1	2	pig44.dat	BLOOD	7.1	
654	8-960328	3	PbAc	225		2.7	2	pig44.dat	BLOOD	2.7	
610	8-960286	7	Butte	75	<	1	2	pig44.dat	BLOOD	0.5	
611	8-960302	7	Butte	75	<	1	2	pig44.dat	BLOOD	0.5	
617	8-960288	7	Butte	75	<	1	2	pig44.dat	BLOOD	0.5	
637	8-960325	7	Butte	75	<	1	2	pig44.dat	BLOOD	0.5	
643	8-960338	7	Butte	75		1	2	pig44.dat	BLOOD	1	
601	8-960292	8	Butte	225		1.6	2	pig44.dat	BLOOD	1.6	
609	8-960299	8	Butte	225		1.3	2	pig44.dat	BLOOD	1.3	
618	8-960309	8	Butte	225		1.2	2	pig44.dat	BLOOD	1.2	
621	8-960336	8	Butte	225		1.9	2	pig44.dat	BLOOD	1.9	
635	8-960285	8	Butte	225		1.1	2	pig44.dat	BLOOD	1.1	
620	8-960333	9	Butte	675		5.5	2	pig44.dat	BLOOD	5.5	
627	8-960295	9	Butte	675		4.8	2	pig44.dat	BLOOD	4.8	
634	8-960313	9	Butte	675		3.2	2	pig44.dat	BLOOD	3.2	
646	8-960339	9	Butte	675		3.7	2	pig44.dat	BLOOD	3.7	
655	8-960315	9	Butte	675		2.8	2	pig44.dat	BLOOD	2.8	
604	8-960294	10	IV	100		9.5	2	pig44.dat	BLOOD	9.5	
606	8-960306	10	IV	100		10.4	2	pig44.dat	BLOOD	10.4	
607	8-960289	10	IV	100		9.4	2	pig44.dat	BLOOD	9.4	
612	8-960296	10	IV	100		9.7	2	pig44.dat	BLOOD	9.7	
625	8-960326	10	IV	100		11.3	2	pig44.dat	BLOOD	11.3	
632	8-960324	10	IV	100		8.6	2	pig44.dat	BLOOD	8.6	
642	8-960307	10	IV	100		8.8	2	pig44.dat	BLOOD	8.8	
648	8-960334	10	IV	100		12.5	2	pig44.dat	BLOOD	12.5	
614	8-960389	1	control	0	<	1	3	pig44.dat	BLOOD	0.5	
638	8-960367	1	control	0	<	1	3	pig44.dat	BLOOD	0.5	
613	8-960394	2	PbAc	75		4.1	3	pig44.dat	BLOOD	4.1	
624	8-960344	2	PbAc	75		3	3	pig44.dat	BLOOD	3	
630	8-960350	2	PbAc	75		1.8	3	pig44.dat	BLOOD	1.8	
639	8-960365	2	PbAc	75		2.9	3	pig44.dat	BLOOD	2.9	
641	8-960340	2	PbAc	75		2.1	3	pig44.dat	BLOOD	2.1	
616	8-960357	3	PbAc	225		3.7	3	pig44.dat	BLOOD	3.7	
644	8-960351	3	PbAc	225		5.4	3	pig44.dat	BLOOD	5.4	
651	8-960368	3	PbAc	225		3.3	3	pig44.dat	BLOOD	3.3	
653	8-960363	3	PbAc	225		6.5	3	pig44.dat	BLOOD	6.5	
654	8-960384	3	PbAc	225		4.4	3	pig44.dat	BLOOD	4.4	
610	8-960380	7	Butte	75		1.1	3	pig44.dat	BLOOD	1.1	
611	8-960382	7	Butte	75		1.1	3	pig44.dat	BLOOD	1.1	
617	8-960390	7	Butte	75		1.2	3	pig44.dat	BLOOD	1.2	
637	8-960377	7	Butte	75		1.6	3	pig44.dat	BLOOD	1.6	
643	8-960371	7	Butte	75			3		BLOOD		Clotted
601	8-960388	8	Butte	225		2.9	3	pig44.dat	BLOOD	2.9	
609	8-960372	8	Butte	225		1.9	3	pig44.dat	BLOOD	1.9	
618	8-960342	8	Butte	225		2.8	3	pig44.dat	BLOOD	2.8	
621	8-960361	8	Butte	225		1.8	3	pig44.dat	BLOOD	1.8	
635	8-960362	8	Butte	225		2	3	pig44.dat	BLOOD	2	
620	8-960364	9	Butte	675		5.4	3	pig44.dat	BLOOD	5.4	
627	8-960345	9	Butte	675		6.1	3	pig44.dat	BLOOD	6.1	
634	8-960348	9	Butte	675		3.2	3	pig44.dat	BLOOD	3.2	
646	8-960352	9	Butte	675		3.4	3	pig44.dat	BLOOD	3.4	
655	8-960374	9	Butte	675		2.8	3	pig44.dat	BLOOD	2.8	
604	8-960341	10	IV	100		10.5	3	pig44.dat	BLOOD	10.5	
606	8-960392	10	IV	100		11.1	3	pig44.dat	BLOOD	11.1	
607	8-960356	10	IV	100		8.9	3	pig44.dat	BLOOD	8.9	
612	8-960376	10	IV	100		10.3	3	pig44.dat	BLOOD	10.3	
625	8-960379	10	IV	100		11.5	3	pig44.dat	BLOOD	11.5	
632	8-960360	10	IV	100		9.7	3	pig44.dat	BLOOD	9.7	
642	8-960375	10	IV	100		9.9	3	pig44.dat	BLOOD	9.9	
648	8-960347	10	IV	100		11.8	3	pig44.dat	BLOOD	11.8	
614	8-960413	1	control	0	<	1	5	pig44.dat	BLOOD	0.5	
638	8-960435	1	control	0	<	1	5	pig44.dat	BLOOD	0.5	
613	8-960401	2	PbAc	75		4	5	pig44.dat	BLOOD	4	
624	8-960415	2	PbAc	75		3.4	5	pig44.dat	BLOOD	3.4	

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value (ug/dL)*	Notes
630	8-960424	2	PbAc	75		2.7	5	pig44.dat	BLOOD	2.7	
639	8-960410	2	PbAc	75		4	5	pig44.dat	BLOOD	4	
641	8-960440	2	PbAc	75		2.1	5	pig44.dat	BLOOD	2.1	
616	8-960420	3	PbAc	225		5.2	5	pig44.dat	BLOOD	5.2	
644	8-960421	3	PbAc	225		6.5	5	pig44.dat	BLOOD	6.5	
651	8-960418	3	PbAc	225		5.7	5	pig44.dat	BLOOD	5.7	
653	8-960434	3	PbAc	225		7.6	5	pig44.dat	BLOOD	7.6	
654	8-960397	3	PbAc	225		4.9	5	pig44.dat	BLOOD	4.9	
610	8-960436	7	Butte	75		2.1	5	pig44.dat	BLOOD	2.1	
611	8-960407	7	Butte	75		1.3	5	pig44.dat	BLOOD	1.3	
617	8-960428	7	Butte	75		1.1	5	pig44.dat	BLOOD	1.1	
637	8-960427	7	Butte	75		1.4	5	pig44.dat	BLOOD	1.4	
643	8-960408	7	Butte	75		1.2	5	pig44.dat	BLOOD	1.2	
601	8-960438	8	Butte	225		2.7	5	pig44.dat	BLOOD	2.7	
609	8-960400	8	Butte	225		2.1	5	pig44.dat	BLOOD	2.1	
618	8-960447	8	Butte	225		2.9	5	pig44.dat	BLOOD	2.9	
621	8-960411	8	Butte	225		2.7	5	pig44.dat	BLOOD	2.7	
635	8-960416	8	Butte	225		2.1	5	pig44.dat	BLOOD	2.1	
620	8-960441	9	Butte	675		7	5	pig44.dat	BLOOD	7	
627	8-960430	9	Butte	675		8.8	5	pig44.dat	BLOOD	8.8	
634	8-960439	9	Butte	675		4.6	5	pig44.dat	BLOOD	4.6	
646	8-960437	9	Butte	675		5.9	5	pig44.dat	BLOOD	5.9	
655	8-960417	9	Butte	675		3.3	5	pig44.dat	BLOOD	3.3	
604	8-960442	10	IV	100		13.2	5	pig44.dat	BLOOD	13.2	
606	8-960448	10	IV	100		12.3	5	pig44.dat	BLOOD	12.3	
607	8-960449	10	IV	100		11.1	5	pig44.dat	BLOOD	11.1	
612	8-960431	10	IV	100		12.6	5	pig44.dat	BLOOD	12.6	
625	8-960399	10	IV	100		13.3	5	pig44.dat	BLOOD	13.3	
632	8-960425	10	IV	100		11.8	5	pig44.dat	BLOOD	11.8	
642	8-960406	10	IV	100		12.8	5	pig44.dat	BLOOD	12.8	
648	8-960444	10	IV	100		15.6	5	pig44.dat	BLOOD	15.6	
614	8-960497	1	control	0		2.6	7	pig44.dat	BLOOD	2.6	
638	8-960456	1	control	0	<	1	7	pig44.dat	BLOOD	0.5	
613	8-960500	2	PbAc	75		5	7	pig44.dat	BLOOD	5	
624	8-960484	2	PbAc	75		2.8	7	pig44.dat	BLOOD	2.8	
630	8-960468	2	PbAc	75		2.5	7	pig44.dat	BLOOD	2.5	
639	8-960480	2	PbAc	75		2.8	7	pig44.dat	BLOOD	2.8	
641	8-960502	2	PbAc	75		3.2	7	pig44.dat	BLOOD	3.2	
616	8-960450	3	PbAc	225		6.5	7	pig44.dat	BLOOD	6.5	
644	8-960467	3	PbAc	225		6.3	7	pig44.dat	BLOOD	6.3	
651	8-960492	3	PbAc	225		1.6	7	pig44.dat	BLOOD	1.6	
653	8-960452	3	PbAc	225		7.9	7	pig44.dat	BLOOD	7.9	
654	8-960462	3	PbAc	225		5	7	pig44.dat	BLOOD	5	
610	8-960474	7	Butte	75		2	7	pig44.dat	BLOOD	2	
611	8-960481	7	Butte	75	<	1	7	pig44.dat	BLOOD	0.5	
617	8-960469	7	Butte	75	<	1	7	pig44.dat	BLOOD	0.5	
637	8-960464	7	Butte	75		1	7	pig44.dat	BLOOD	1	
643	8-960491	7	Butte	75		1.9	7	pig44.dat	BLOOD	1.9	
601	8-960457	8	Butte	225		2.9	7	pig44.dat	BLOOD	2.9	
609	8-960496	8	Butte	225		2	7	pig44.dat	BLOOD	2	
618	8-960485	8	Butte	225		2.9	7	pig44.dat	BLOOD	2.9	
621	8-960501	8	Butte	225		3.4	7	pig44.dat	BLOOD	3.4	
635	8-960466	8	Butte	225		2.4	7	pig44.dat	BLOOD	2.4	
620	8-960459	9	Butte	675		8	7	pig44.dat	BLOOD	8	
627	8-960478	9	Butte	675		6.5	7	pig44.dat	BLOOD	6.5	
634	8-960477	9	Butte	675		3.5	7	pig44.dat	BLOOD	3.5	
646	8-960494	9	Butte	675		4.6	7	pig44.dat	BLOOD	4.6	
655	8-960455	9	Butte	675		4.2	7	pig44.dat	BLOOD	4.2	
604	8-960460	10	IV	100		13.5	7	pig44.dat	BLOOD	13.5	
606	8-960504	10	IV	100		4.9	7	pig44.dat	BLOOD	4.9	
607	8-960451	10	IV	100		11.7	7	pig44.dat	BLOOD	11.7	
612	8-960465	10	IV	100		12.3	7	pig44.dat	BLOOD	12.3	
625	8-960453	10	IV	100		15.5	7	pig44.dat	BLOOD	15.5	
632	8-960472	10	IV	100		11.6	7	pig44.dat	BLOOD	11.6	
642	8-960488	10	IV	100		12.2	7	pig44.dat	BLOOD	12.2	
648	8-960498	10	IV	100	<	1	7	pig44.dat	BLOOD	0.5	
614	8-960526	1	control	0	<	1	9	pig44.dat	BLOOD	0.5	
638	8-960528	1	control	0	<	1	9	pig44.dat	BLOOD	0.5	
613	8-960510	2	PbAc	75		4.3	9	pig44.dat	BLOOD	4.3	
624	8-960537	2	PbAc	75		3.2	9	pig44.dat	BLOOD	3.2	
630	8-960549	2	PbAc	75		3.4	9	pig44.dat	BLOOD	3.4	
639	8-960530	2	PbAc	75		4.9	9	pig44.dat	BLOOD	4.9	
641	8-960506	2	PbAc	75		3.8	9	pig44.dat	BLOOD	3.8	
616	8-960518	3	PbAc	225		4.1	9	pig44.dat	BLOOD	4.1	
644	8-960541	3	PbAc	225		1.1	9	pig44.dat	BLOOD	1.1	
651	8-960539	3	PbAc	225		7	9	pig44.dat	BLOOD	7	
653	8-960553	3	PbAc	225		8.7	9	pig44.dat	BLOOD	8.7	
654	8-960536	3	PbAc	225		6.2	9	pig44.dat	BLOOD	6.2	
610	8-960529	7	Butte	75		1.7	9	pig44.dat	BLOOD	1.7	
611	8-960548	7	Butte	75		1	9	pig44.dat	BLOOD	1	
617	8-960534	7	Butte	75		1.2	9	pig44.dat	BLOOD	1.2	
637	8-960540	7	Butte	75		7	9	pig44.dat	BLOOD	7	
643	8-960546	7	Butte	75	<	1	9	pig44.dat	BLOOD	0.5	
601	8-960517	8	Butte	225		2.6	9	pig44.dat	BLOOD	2.6	
609	8-960550	8	Butte	225		2.6	9	pig44.dat	BLOOD	2.6	
618	8-960511	8	Butte	225		3.3	9	pig44.dat	BLOOD	3.3	
621	8-960520	8	Butte	225		5.7	9	pig44.dat	BLOOD	5.7	
635	8-960512	8	Butte	225		3	9	pig44.dat	BLOOD	3	
620	8-960525	9	Butte	675		8.9	9	pig44.dat	BLOOD	8.9	
627	8-960514	9	Butte	675		6.6	9	pig44.dat	BLOOD	6.6	
634	8-960542	9	Butte	675		4.2	9	pig44.dat	BLOOD	4.2	

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value (ug/dL)[a]	Notes
646	8-960552	9	Butte	675		6.1	9	pig44.dat	BLOOD	6.1	
655	8-960524	9	Butte	675		4.5	9	pig44.dat	BLOOD	4.5	
604	8-960505	10	IV	100		12.3	9	pig44.dat	BLOOD	12.3	
606	8-960554	10	IV	100		13.1	9	pig44.dat	BLOOD	13.1	
607	8-960543	10	IV	100		11.9	9	pig44.dat	BLOOD	11.9	
612	8-960535	10	IV	100		13.4	9	pig44.dat	BLOOD	13.4	
625	8-960527	10	IV	100		13.7	9	pig44.dat	BLOOD	13.7	
632	8-960508	10	IV	100		12.2	9	pig44.dat	BLOOD	12.2	
642	8-960545	10	IV	100		13.8	9	pig44.dat	BLOOD	13.8	
648	8-960516	10	IV	100		15	9	pig44.dat	BLOOD	15	
614	8-960602	1	control	0	<	1	12	pig44.dat	BLOOD	0.5	
638	8-960578	1	control	0	<	1	12	pig44.dat	BLOOD	0.5	
613	8-960566	2	PbAc	75		4.5	12	pig44.dat	BLOOD	4.5	
624	8-960608	2	PbAc	75		5.7	12	pig44.dat	BLOOD	5.7	
630	8-960577	2	PbAc	75		2.9	12	pig44.dat	BLOOD	2.9	
639	8-960560	2	PbAc	75		5.2	12	pig44.dat	BLOOD	5.2	
641	8-960592	2	PbAc	75		6.1	12	pig44.dat	BLOOD	6.1	
616	8-960594	3	PbAc	225		5.8	12	pig44.dat	BLOOD	5.8	
644	8-960601	3	PbAc	225		7.2	12	pig44.dat	BLOOD	7.2	
651	8-960574	3	PbAc	225		6.3	12	pig44.dat	BLOOD	6.3	
653	8-960604	3	PbAc	225		7.9	12	pig44.dat	BLOOD	7.9	
654	8-960580	3	PbAc	225		5.8	12	pig44.dat	BLOOD	5.8	
610	8-960563	7	Butte	75		1.4	12	pig44.dat	BLOOD	1.4	
611	8-960585	7	Butte	75		1.3	12	pig44.dat	BLOOD	1.3	
617	8-960572	7	Butte	75	<	1	12	pig44.dat	BLOOD	0.5	
637	8-960609	7	Butte	75		1.9	12	pig44.dat	BLOOD	1.9	
643	8-960593	7	Butte	75		1.7	12	pig44.dat	BLOOD	1.7	
601	8-960576	8	Butte	225		3.3	12	pig44.dat	BLOOD	3.3	
609	8-960605	8	Butte	225		2.1	12	pig44.dat	BLOOD	2.1	
618	8-960596	8	Butte	225		3.5	12	pig44.dat	BLOOD	3.5	
621	8-960598	8	Butte	225		3.2	12	pig44.dat	BLOOD	3.2	
635	8-960573	8	Butte	225		2.8	12	pig44.dat	BLOOD	2.8	
620	8-960568	9	Butte	675		8.3	12	pig44.dat	BLOOD	8.3	
627	8-960606	9	Butte	675		7	12	pig44.dat	BLOOD	7	
634	8-960582	9	Butte	675		4.9	12	pig44.dat	BLOOD	4.9	
646	8-960614	9	Butte	675		5.8	12	pig44.dat	BLOOD	5.8	
656	8-960575	9	Butte	675		4.4	12	pig44.dat	BLOOD	4.4	
604	8-960603	10	IV	100		12.4	12	pig44.dat	BLOOD	12.4	
606	8-960561	10	IV	100		12	12	pig44.dat	BLOOD	12	
607	8-960612	10	IV	100		13.1	12	pig44.dat	BLOOD	13.1	
612	8-960597	10	IV	100		13	12	pig44.dat	BLOOD	13	
625	8-960613	10	IV	100		13.3	12	pig44.dat	BLOOD	13.3	
632	8-960570	10	IV	100		10.9	12	pig44.dat	BLOOD	10.9	
642	8-960583	10	IV	100		13.5	12	pig44.dat	BLOOD	13.5	
648	8-960564	10	IV	100		12.7	12	pig44.dat	BLOOD	12.7	
614	8-960628	1	control	0	<	1	15	pig44.dat	BLOOD	0.5	
638	8-960622	1	control	0		1	15	pig44.dat	BLOOD	1	
613	8-960626	2	PbAc	75		6.7	15	pig44.dat	BLOOD	6.7	
624	8-960621	2	PbAc	75		6.2	15	pig44.dat	BLOOD	6.2	
630	8-960666	2	PbAc	75		4.6	15	pig44.dat	BLOOD	4.6	
639	8-960657	2	PbAc	75		4.7	15	pig44.dat	BLOOD	4.7	
641	8-960642	2	PbAc	75		4.5	15	pig44.dat	BLOOD	4.5	
616	8-960650	3	PbAc	225		5.1	15	pig44.dat	BLOOD	5.1	
644	8-960656	3	PbAc	225		9.3	15	pig44.dat	BLOOD	9.3	
651	8-960648	3	PbAc	225		8.1	15	pig44.dat	BLOOD	8.1	
653	8-960625	3	PbAc	225		8.1	15	pig44.dat	BLOOD	8.1	
654	8-960629	3	PbAc	225		8.2	15	pig44.dat	BLOOD	8.2	
610	8-960623	7	Butte	75		2.2	15	pig44.dat	BLOOD	2.2	
611	8-960616	7	Butte	75		1.7	15	pig44.dat	BLOOD	1.7	
617	8-960660	7	Butte	75		1.2	15	pig44.dat	BLOOD	1.2	
637	8-960654	7	Butte	75		2.4	15	pig44.dat	BLOOD	2.4	
643	8-960646	7	Butte	75		1.5	15	pig44.dat	BLOOD	1.5	
601	8-960634	8	Butte	225		3.6	15	pig44.dat	BLOOD	3.6	
609	8-960655	8	Butte	225		3.6	15	pig44.dat	BLOOD	3.6	
618	8-960638	8	Butte	225		2.9	15	pig44.dat	BLOOD	2.9	
621	8-960661	8	Butte	225		3.1	15	pig44.dat	BLOOD	3.1	
635	8-960631	8	Butte	225		4.2	15	pig44.dat	BLOOD	4.2	
620	8-960669	9	Butte	675		8.6	15	pig44.dat	BLOOD	8.6	
627	8-960647	9	Butte	675		8.4	15	pig44.dat	BLOOD	8.4	
634	8-960615	9	Butte	675		4.8	15	pig44.dat	BLOOD	4.8	
646	8-960649	9	Butte	675		6	15	pig44.dat	BLOOD	6	
655	8-960663	9	Butte	675		4.8	15	pig44.dat	BLOOD	4.8	
604	8-960637	10	IV	100		15.5	15	pig44.dat	BLOOD	15.5	
606	8-960635	10	IV	100		13.7	15	pig44.dat	BLOOD	13.7	
607	8-960668	10	IV	100		12.4	15	pig44.dat	BLOOD	12.4	
612	8-960665	10	IV	100		13.8	15	pig44.dat	BLOOD	13.8	
625	8-960617	10	IV	100		13.8	15	pig44.dat	BLOOD	13.8	
632	8-960653	10	IV	100		11.5	15	pig44.dat	BLOOD	11.5	
642	8-960658	10	IV	100		14.7	15	pig44.dat	BLOOD	14.7	
648	8-960636	10	IV	100		17.2	15	pig44.dat	BLOOD	17.2	

a Non-detects evaluated using 1/2 the quantitation limit; laboratory results (ug/L) converted to concentration in blood (ug/dL) by dividing by dilution factor of 1 dL/L.

TABLE A-4 BLOOD LEAD OUTLIERS

Flagged Data Points
Outliers

test material	target dosage	Actual Dose*	group	pig#	BLOOD LEAD (ug/dL) BY DAY									
					-4	0	1	2	3	5	7	9	12	15
control	0	0.00	1	614	0.5	0.5	0.5	0.5	0.5	0.5	2.6	0.5	0.5	0.5
control	0	0.00	1	638	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
PbAc	75	70.99	2	613	0.5	0.5	1.2	3.4	4.1	4	5	4.3	4.5	6.7
PbAc	75	79.09	2	624	0.5	1	2.4	2.9	3	3.4	2.8	3.2	5.7	6.2
PbAc	75	75.53	2	630	0.5	0.5	1.2	1.2	1.8	2.7	2.5	3.4	2.9	4.6
PbAc	75	69.05	2	639	0.5	0.5	2.1	2.6	2.9	4	2.8	4.9	5.2	4.7
PbAc	75	86.65	2	641	0.5	0.5	0.5	1.5	2.1	2.1	3.2	3.8	6.1	4.5
PbAc	225	300.50	3	616	0.5	0.5	1.7	3	3.7	5.2	6.5	4.1	5.8	5.1
PbAc	225	253.58	3	644	0.5	0.5	2.8	4.3	5.4	6.5	6.3	7.1	7.2	9.3
PbAc	225	230.18	3	651	0.5	0.5	1.9	2.1	3.3	5.7	1.5	7	6.3	8.1
PbAc	225	236.49	3	653	0.5	0.5	3.8	7.1	6.5	7.6	7.9	8.7	7.9	8.1
PbAc	225	241.19	3	654	0.5	0.5	3	2.7	4.4	4.9	5	6.2	5.8	8.2
Butte	75	69.25	7	610	0.5	0.5	0.5	0.5	1.1	2.1	2	1.7	1.4	2.2
Butte	75	82.63	7	611	0.5	0.5	0.5	0.5	1.1	1.3	0.5	1	1.3	1.7
Butte	75	71.47	7	617	0.5	0.5	0.5	0.5	1.2	1.1	0.5	1.2	0.5	1.2
Butte	75	76.22	7	637	0.5	0.5	0.5	0.5	1.6	1.4	1	7	1.9	2.4
Butte	75	70.66	7	643	0.5	0.5	0.5	1	Clotted	1.2	1.9	0.5	1.7	1.5
Butte	225	210.42	8	601	0.5	0.5	1.4	1.6	2.9	2.7	2.9	2.6	3.3	3.6
Butte	225	249.23	8	609	0.5	0.5	0.5	1.3	1.9	2.1	2	2.6	2.1	3.6
Butte	225	213.10	8	618	0.5	1.1	1.5	1.2	2.8	2.9	2.9	3.3	3.5	2.9
Butte	225	209.77	8	621	0.5	0.5	0.5	1.9	1.8	2.7	3.4	5.7	3.2	3.1
Butte	225	257.73	8	635	0.5	0.5	0.5	1.1	2	2.1	2.4	3	2.8	4.2
Butte	675	720.77	9	620	0.5	0.5	3.3	5.5	5.4	7	8	8.9	8.3	8.6
Butte	675	629.49	9	627	0.5	0.5	3.6	4.8	6.1	6.8	6.5	6.6	7	8.4
Butte	675	786.57	9	634	0.5	0.5	1.7	3.2	3.2	4.6	3.5	4.2	4.9	4.6
Butte	675	696.64	9	646	0.5	0.5	1.4	3.7	3.4	5.9	4.6	6.1	5.8	6
Butte	675	601.38	9	655	0.5	0.5	1.7	2.8	2.8	3.3	4.2	4.5	4.4	4.8
IV	100	105.19	10	604	0.5	0.5	6.6	9.5	10.5	13.2	13.5	12.3	12.4	15.5
IV	100	101.77	10	606	0.5	0.5	7.5	10.4	11.1	12.3	4.9	13.1	12	13.7
IV	100	85.41	10	607	0.5	0.5	8.2	9.4	8.9	11.1	11.7	11.9	13.1	12.4
IV	100	105.64	10	612	0.5	1.1	9.2	9.7	10.3	12.6	12.3	13.4	13	13.8
IV	100	96.30	10	625	0.5	0.5	8	11.3	11.5	13.3	15.5	13.7	13.3	13.8
IV	100	104.02	10	632	0.5	0.5	6.6	8.6	9.7	11.8	11.6	12.2	10.9	11.5
IV	100	93.59	10	642	0.5	0.5	7.3	8.8	9.9	12.8	12.2	13.8	13.5	14.7
IV	100	126.06	10	648	0.5	0.5	8.4	12.5	11.8	15.6	0.5	15	12.7	17.2

*** Average Time and Weight-Adjusted Dose for Each Pig**

TABLE A-5 RATIONALE FOR PbB OUTLIER DECISIONS

OUTLIER	IDENTIFICATION	RATIONALE
1	Day 7 Group 1 Pig # 614	Based on comparison with responses by other animals in this group on this day, the response of animal 614 is notably higher. Therefore, this value is excluded and replaced with an interpolated value of 0.5 ug/dL.
2	Day 7 Group 3 Pig # 651	Based on the time-trend for this animal, the PbB on day 7 is substantially lower than expected from the PbB values measured before and after: Day PbB 5 5.7 7 1.6 9 7.0 Also, based on comparison with responses by other animals in this group on this day, the response of animal 651 is notably lower. Therefore, this value is excluded and replaced with an interpolated value (6.35 ug/dL).
3	Day 7 Group 10 Pig # 606	Based on the time-trend for this animal, the PbB on day 7 is substantially lower than expected from the PbB values measured before and after: Day PbB 5 12.3 7 4.9 9 13.1 Also, based on comparison with responses by other animals in this group on this day, the response of animal 606 is notably lower. Therefore, this value is excluded and replaced with an interpolated value (12.7 ug/dL).
4	Day 7 Group 10 Pig # 648	Based on the time-trend for this animal, the PbB on day 7 is substantially lower than expected from the PbB values measured before and after: Day PbB 5 15.6 7 0.5 9 15.0 Also, based on comparison with responses by other animals in this group on this day, the response of animal 648 is notably lower. Therefore, this value is excluded and replaced with an interpolated value (15.3 ug/dL).
5	Day 9 Group 3 Pig # 644	Based on the time-trend for this animal, the PbB on day 9 is substantially lower than expected from the PbB values measured before and after: Day PbB 7 6.3 9 1.1 12 7.2 Also, based on comparison with responses by other animals in this group on this day, the response of animal 644 is notably lower. Therefore, this value is excluded and replaced with an interpolated value (6.66 ug/dL).
6	Day 9 Group 7 Pig # 637	Based on the time-trend for this animal, the PbB on day 9 is substantially higher than expected from the PbB values measured before and after: Day PbB 7 1.0 9 7.0 12 1.9 Also, based on comparison with responses by other animals in this group on this day, the response of animal 637 is notably higher. Therefore, this value is excluded and replaced with an interpolated value (1.36 ug/dL).
7	Day 9 Group 8 Pig # 621	Based on the time-trend for this animal, the PbB on day 9 is substantially higher than expected from the PbB values measured before and after: Day PbB 7 3.4 9 5.7 12 3.0 Also, based on comparison with responses by other animals in this group on this day, the response of animal 621 is notably higher. Therefore, this value is excluded and replaced with an interpolated value (3.32 ug/dL).

TABLE A-6 Area Under Curve Determinations

Calculated using interpolated values for missing or excluded data as noted in Table A-5

		AUC (ug/dL-days) For Time Span Shown								AUC Total
group	pig#	0-1	1-2	2-3	3-5	5-7	7-9	9-12	12-15	(ug/dL-days)
1	614	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
1	638	0.50	0.50	0.50	1.00	1.00	1.00	1.50	2.25	8.25
2	613	0.85	2.30	3.75	8.10	9.00	9.30	13.20	16.80	63.30
2	624	1.70	2.65	2.95	6.40	6.20	6.00	13.35	17.85	57.10
2	630	0.85	1.20	1.50	4.50	5.20	5.90	9.45	11.25	39.85
2	639	1.30	2.35	2.75	6.90	6.80	7.70	15.15	14.85	57.80
2	641	0.50	1.00	1.80	4.20	5.30	7.00	14.85	15.90	50.55
3	616	1.10	2.35	3.35	8.90	11.70	10.60	14.85	16.35	69.20
3	644	1.65	3.55	4.85	11.90	12.80	12.96	20.79	24.75	93.25
3	651	1.20	2.00	2.70	9.00	12.05	13.35	19.95	21.60	81.85
3	653	2.15	5.45	6.80	14.10	15.50	16.60	24.90	24.00	109.50
3	654	1.75	2.85	3.55	9.30	9.90	11.20	18.00	21.00	77.55
7	610	0.50	0.50	0.80	3.20	4.10	3.70	4.65	5.40	22.85
7	611	0.50	0.50	0.80	2.40	1.80	1.50	3.45	4.50	15.45
7	617	0.50	0.50	0.85	2.30	1.60	1.70	2.55	2.55	12.55
7	637	0.50	0.50	1.05	3.00	2.40	2.36	4.89	6.45	21.15
7	643	0.50	0.75	1.02	2.23	3.10	2.40	3.30	4.80	18.10
8	601	0.95	1.50	2.25	5.60	5.60	5.50	8.85	10.35	40.60
8	609	0.50	0.90	1.60	4.00	4.10	4.60	7.05	8.55	31.30
8	618	1.30	1.35	2.00	5.70	5.80	6.20	10.20	9.60	42.15
8	621	0.50	1.20	1.85	4.50	6.10	6.72	9.78	9.45	40.10
8	635	0.50	0.80	1.55	4.10	4.50	5.40	8.70	10.50	36.05
9	620	1.90	4.40	5.45	12.40	15.00	16.90	25.80	25.35	107.20
9	627	2.05	4.20	5.45	14.90	15.30	13.10	20.40	23.10	98.50
9	634	1.10	2.45	3.20	7.80	8.10	7.70	13.65	14.55	58.55
9	646	0.95	2.55	3.55	9.30	10.50	10.70	17.85	17.70	73.10
9	655	1.10	2.25	2.80	6.10	7.50	8.70	13.35	13.80	55.60
10	604	3.55	8.05	10.00	23.70	26.70	25.80	37.05	41.85	176.70
10	606	4.00	8.95	10.75	23.40	25.00	25.80	37.65	38.55	174.10
10	607	4.35	8.80	9.15	20.00	22.80	23.60	37.50	38.25	164.45
10	612	5.15	9.45	10.00	22.90	24.90	25.70	39.60	40.20	177.90
10	625	4.25	9.65	11.40	24.80	28.80	29.20	40.50	40.65	189.25
10	632	3.55	7.60	9.15	21.50	23.40	23.80	34.65	33.60	157.25
10	642	3.90	8.05	9.35	22.70	25.00	26.00	40.95	42.30	178.25
10	648	4.45	10.45	12.15	27.40	30.90	30.30	41.55	44.85	202.05

TABLE A - 7 TISSUE LEAD DATA

PHASE II EXPERIMENT 6 (Data not shown for groups 4, 5, & 6)

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value*	Notes
614	8-960839	1	control	0	<	2	15	T960106F	FEMUR	0.5	
638	8-960854	1	control	0		7.6	15	T960106F	FEMUR	3.8	
613	8-960833	2	PbAc	75		6.4	15	T960106F	FEMUR	3.2	
624	8-960871	2	PbAc	75		8.9	15	T960106F	FEMUR	4.45	
630	8-960863	2	PbAc	75		8	15	T960106F	FEMUR	4	
639	8-960832	2	PbAc	75		3.7	15	T960106F	FEMUR	1.85	
641	8-960872	2	PbAc	75		8	15	T960106F	FEMUR	4	
616	8-960840	3	PbAc	225		13.2	15	T960106F	FEMUR	6.6	
644	8-960870	3	PbAc	225		35.8	15	T960106F	FEMUR	17.9	
651	8-960868	3	PbAc	225		21.6	15	T960106F	FEMUR	10.8	
653	8-960825	3	PbAc	225		26.1	15	T960106F	FEMUR	13.05	
654	8-960845	3	PbAc	225		19.1	15	T960106F	FEMUR	9.55	
610	8-960857	7	Butte	75	<	2	15	T960106F	FEMUR	0.5	
611	8-960828	7	Butte	75	<	2	15	T960106F	FEMUR	0.5	
617	8-960831	7	Butte	75	<	2	15	T960106F	FEMUR	0.5	
637	8-960861	7	Butte	75	<	2	15	T960106F	FEMUR	0.5	
643	8-960853	7	Butte	75	<	2	15	T960106F	FEMUR	0.5	
601	8-960836	8	Butte	225	<	2	15	T960106F	FEMUR	0.5	
609	8-960834	8	Butte	225	<	2	15	T960106F	FEMUR	0.5	
618	8-960860	8	Butte	225		5.2	15	T960106F	FEMUR	2.6	
621	8-960864	8	Butte	225		3.5	15	T960106F	FEMUR	1.75	
635	8-960852	8	Butte	225	<	2	15	T960106F	FEMUR	0.5	
620	8-960838	9	Butte	675		12.6	15	T960106F	FEMUR	6.3	
627	8-960856	9	Butte	675		19.6	15	T960106F	FEMUR	9.8	
634	8-960850	9	Butte	675		8.1	15	T960106F	FEMUR	4.05	
646	8-960847	9	Butte	675		13.8	15	T960106F	FEMUR	6.9	
655	8-960843	9	Butte	675		3	15	T960106F	FEMUR	1.5	
604	8-960827	10	IV	100		73	15	T960106F	FEMUR	36.5	
606	8-960826	10	IV	100		71.3	15	T960106F	FEMUR	35.65	
607	8-960866	10	IV	100		75.7	15	T960106F	FEMUR	37.85	
612	8-960855	10	IV	100		130	15	T960106F	FEMUR	65	
625	8-960851	10	IV	100		82.8	15	T960106F	FEMUR	41.4	
632	8-960829	10	IV	100		76.3	15	T960106F	FEMUR	38.15	
642	8-960835	10	IV	100		58.3	15	T960106F	FEMUR	29.15	
648	8-960858	10	IV	100		104	15	T960106F	FEMUR	52	
614	8-960785	1	control	0		4.7	15	T951213K	KIDNEY	47	
638	8-960797	1	control	0		152	15	T951213K	KIDNEY	1520	
613	8-960821	2	PbAc	75		22.8	15	T951213K	KIDNEY	228	
624	8-960814	2	PbAc	75		18.4	15	T951213K	KIDNEY	184	
630	8-960772	2	PbAc	75		14.2	15	T951213K	KIDNEY	142	
639	8-960786	2	PbAc	75		20	15	T951213K	KIDNEY	200	
641	8-960817	2	PbAc	75		16.7	15	T951213K	KIDNEY	167	
616	8-960823	3	PbAc	225		30.1	15	T951213K	KIDNEY	301	
644	8-960791	3	PbAc	225		72.5	15	T951213K	KIDNEY	725	
651	8-960799	3	PbAc	225		39.9	15	T951213K	KIDNEY	399	
653	8-960787	3	PbAc	225		66	15	T951213K	KIDNEY	660	
654	8-960805	3	PbAc	225		62	15	T951213K	KIDNEY	620	
610	8-960803	7	Butte	75		2.6	15	T951213K	KIDNEY	26	
611	8-960781	7	Butte	75		3.7	15	T951213K	KIDNEY	37	
617	8-960777	7	Butte	75		1.9	15	T951213K	KIDNEY	19	
637	8-960806	7	Butte	75		3.3	15	T951213K	KIDNEY	33	
643	8-960807	7	Butte	75		2.4	15	T951213K	KIDNEY	24	
601	8-960801	8	Butte	225		8.9	15	T951213K	KIDNEY	89	
609	8-960789	8	Butte	225		11.5	15	T951213K	KIDNEY	115	
618	8-960788	8	Butte	225		13.3	15	T951213K	KIDNEY	133	
621	8-960773	8	Butte	225		6.3	15	T951213K	KIDNEY	63	
635	8-960780	8	Butte	225		8.5	15	T951213K	KIDNEY	85	
620	8-960811	9	Butte	675		30.4	15	T951213K	KIDNEY	304	
627	8-960784	9	Butte	675		71	15	T951213K	KIDNEY	710	
634	8-960808	9	Butte	675		19.3	15	T951213K	KIDNEY	193	
646	8-960818	9	Butte	675		27.6	15	T951213K	KIDNEY	276	
655	8-960816	9	Butte	675		16	15	T951213K	KIDNEY	160	
604	8-960771	10	IV	100		122	15	T951213K	KIDNEY	1220	
606	8-960820	10	IV	100		109	15	T951213K	KIDNEY	1090	
607	8-960802	10	IV	100		148.2	15	T951213K	KIDNEY	1482	
612	8-960804	10	IV	100		123	15	T951213K	KIDNEY	1230	
625	8-960815	10	IV	100		133	15	T951213K	KIDNEY	1330	
632	8-960783	10	IV	100		106	15	T951213K	KIDNEY	1060	
642	8-960810	10	IV	100		135	15	T951213K	KIDNEY	1350	
648	8-960790	10	IV	100		135	15	T951213K	KIDNEY	1350	
614	8-960762	1	control	0		7.2	15	T960105L	LIVER	72	
638	8-960752	1	control	0		118	15	T960105L	LIVER	1180	
613	8-960729	2	PbAc	75		16.6	15	T960105L	LIVER	166	
624	8-960755	2	PbAc	75		15.4	15	T960105L	LIVER	154	
630	8-960720	2	PbAc	75		17.6	15	T960105L	LIVER	176	
639	8-960724	2	PbAc	75		16.6	15	T960105L	LIVER	166	
641	8-960736	2	PbAc	75		16.2	15	T960105L	LIVER	162	
616	8-960753	3	PbAc	225		33.5	15	T960105L	LIVER	335	
644	8-960738	3	PbAc	225		56	15	T960105L	LIVER	560	
651	8-960721	3	PbAc	225		73	15	T960105L	LIVER	730	
653	8-960726	3	PbAc	225		86	15	T960105L	LIVER	860	
654	8-960766	3	PbAc	225		55	15	T960105L	LIVER	550	
610	8-960747	7	Butte	75		4.1	15	T960105L	LIVER	41	
611	8-960727	7	Butte	75		5.2	15	T960105L	LIVER	52	
617	8-960751	7	Butte	75		1.8	15	T960105L	LIVER	18	
637	8-960757	7	Butte	75		2.5	15	T960105L	LIVER	25	
643	8-960745	7	Butte	75		3.7	15	T960105L	LIVER	37	
601	8-960750	8	Butte	225		12.6	15	T960105L	LIVER	126	

pig number	sample	group	material administered	dosage	qualifier	lab result (ug/L)	day	source file	MATRIX	Adjusted Value[a]	Notes
609	8-960743	8	Butte	225		10.5	15	T960105L	LIVER	105	
618	8-960754	8	Butte	225		12.5	15	T960105L	LIVER	125	
621	8-960760	8	Butte	225		6.9	15	T960105L	LIVER	69	
635	8-960728	8	Butte	225		7.6	15	T960105L	LIVER	76	
620	8-960748	9	Butte	675		26.9	15	T960105L	LIVER	269	
627	8-960761	9	Butte	675		41	15	T960105L	LIVER	410	
634	8-960730	9	Butte	675		14.8	15	T960105L	LIVER	148	
646	8-960737	9	Butte	675		21.3	15	T960105L	LIVER	213	
655	8-960740	9	Butte	675		11	15	T960105L	LIVER	110	
604	8-960732	10	IV	100		98	15	T960105L	LIVER	980	
606	8-960764	10	IV	100		110	15	T960105L	LIVER	1100	
607	8-960769	10	IV	100		159	15	T960105L	LIVER	1590	
612	8-960725	10	IV	100		164	15	T960105L	LIVER	1640	
625	8-960767	10	IV	100		154	15	T960105L	LIVER	1540	
632	8-960763	10	IV	100		127	15	T960105L	LIVER	1270	
642	8-960770	10	IV	100		137	15	T960105L	LIVER	1370	
648	8-960741	10	IV	100		197	15	T960105L	LIVER	1970	

a Non-detects evaluated using 1/2 the quantitation limit. Laboratory results (ug/L) converted to tissue concentrations by dividing by sample dilution factors of 0.1 kg/L (liver, kidney) or 2 g/L (ashed bone). Final units are ug Pb/kg wet weight (liver, kidney) or ug Pb/g ashed bone (femur).

TABLE A-8 SUMMARY OF ENDPOINT OUTLIERS

[ ] Selected Outliers

test material	target dosage	Actual Dose*	group	pig#	MEASUREMENT ENDPOINT Blood	Femur	Liver	Kidney
control	0	0.00	1	614	7.5	0.5	72	47
control	0	0.00	1	638	8.3	[3.8] a1	[1180] a1	[1520] a1
PbAc	75	70.99	2	613	63.3	3.2	166	228
PbAc	75	79.09	2	624	57.1	4.45	154	184
PbAc	75	75.53	2	630	39.9	4	176	142
PbAc	75	69.05	2	639	57.8	1.85	166	200
PbAc	75	86.65	2	641	50.6	4	162	167
PbAc	225	300.50	3	616	69.2	6.6	335	301
PbAc	225	253.58	3	644	93.3	17.9	560	725
PbAc	225	230.18	3	651	81.9	10.8	730	399
PbAc	225	236.49	3	653	109.5	13.05	860	660
PbAc	225	241.19	3	654	77.6	9.55	550	620
Butte	75	69.25	7	610	22.9	0.5	41	26
Butte	75	82.63	7	611	15.5	0.5	52	37
Butte	75	71.47	7	617	12.6	0.5	18	19
Butte	75	76.22	7	637	21.2	0.5	25	33
Butte	75	70.66	7	643	18.1	0.5	37	24
Butte	225	210.42	8	601	40.6	0.5	126	89
Butte	225	249.23	8	609	31.3	0.5	105	115
Butte	225	213.10	8	618	42.2	2.6	125	133
Butte	225	209.77	8	621	40.1	1.75	69	63
Butte	225	257.73	8	635	36.1	0.5	76	85
Butte	675	720.77	9	620	107.2	6.3	269	304
Butte	675	629.49	9	627	98.5	[9.8] b	[410] b	[710] b
Butte	675	786.57	9	634	58.6	4.05	148	193
Butte	675	696.64	9	646	73.1	6.9	213	276
Butte	675	601.38	9	655	55.6	1.5	110	160
IV	100	105.19	10	604	176.7	36.5	980	1220
IV	100	101.77	10	606	174.1	35.65	1100	1090
IV	100	85.41	10	607	164.5	37.85	1590	1482
IV	100	105.64	10	612	177.9	65	1640	1230
IV	100	96.30	10	625	189.3	41.4	1540	1330
IV	100	104.02	10	632	157.3	38.15	1270	1060
IV	100	93.59	10	642	178.3	29.15	1370	1350
IV	100	126.06	10	648	202.1	52	1970	1350

a *a priori* outlier determinations

a1 - These two control values were excluded based on the fact that the values were abnormally high compared to data from other studies, and were also higher than those for the low dose PbAc group

b Outside 95% Prediction Interval

TABLE A-9 Best Curve Fit Parameters

BLOOD

PbAc Curve -	Exp
a	8
b	
c	92
d	0.0086
R2	0.893

Butte Curve -	Exp
a	8
b	
c	92
d	0.0019
R2	0.837

BONE

PbAc Curve -	Linear
a	0.45
b	0.043
c	
d	
R2	0.727

Butte Curve -	Linear
a	0.45
b	0.0057
c	
d	
R2	0.669

LIVER

PbAc Curve -	Linear
a	54.4
b	2.052
c	
d	
R2	0.692

Butte Curve -	Linear
a	54.4
b	0.183
c	
d	
R2	0.641

KIDNEY

PbAc Curve -	Linear
a	39.5
b	1.858
c	
d	
R2	0.727

Butte Curve -	Linear
a	39.5
b	0.24
c	
d	
R2	0.773

Equations Used	
EXP	Y=a+c*(1-exp(-d*dose))
LIN	Y=a+b*dose

TABLE A-10 Relative Bioavailability of Lead in Test Materials

Endpoint	Test Material Butte
Blood	0.22
Liver	0.09
Kidney	0.13
Bone	0.13

Definitions

Plausible Range:	RBA(Blood) to mean RBA for Tissues
Preferred Range:	RBA(Blood) to (RBA(Blood) + RBA(Tissues))/2
Suggested Point Est:	1/2(RBA(Blood) + (RBA(Blood)+RBA(Tissues))/2)

Relative Bioavailability

	Butte	
Plausible Range	0.22	0.12
Preferred Range	0.22	0.17
Point Estimate	0.19	

Absolute Bioavailability

	Butte	
Plausible Range	11%	6%
Preferred Range	11%	8%
Point Estimate	10%	

TABLE A-11 INTRALABORATORY DUPLICATES

RPD = Relative Percent Difference
RPD = 100*[Orig-Dup]/((Orig+Dup)/2

* Non detects evaluated at 1/2 DL

Pig number	group	material administered	dosage	day	matrix	Duplicate Value*	Original Value*	Average	RPD	Avg RPD	
653	3	PbAc	225	-4	BLOOD	0.5	0.5	0.5	0%		
617	7	Butte	75	-4	BLOOD	0.5	0.5	0.5	0%		
609	8	Butte	225	-4	BLOOD	0.5	0.5	0.5	0%		
639	2	PbAc	75	0	BLOOD	0.5	0.5	0.5	0%		
645	6	Midvale Slag	675	0	BLOOD	0.5	0.5	0.5	0%		
655	9	Butte	675	0	BLOOD	0.5	0.5	0.5	0%		
651	3	PbAc	225	1	BLOOD	0.5	1.9	1.2	117%		
626	4	Midvale Slag	75	1	BLOOD	0.5	0.5	0.5	0%		
650	5	Midvale Slag	225	1	BLOOD	0.5	1.1	0.8	75%		
631	4	Midvale Slag	75	2	BLOOD	0.5	0.5	0.5	0%		
605	5	Midvale Slag	225	2	BLOOD	1.5	2.2	1.85	38%		
604	10	IV	100	2	BLOOD	10.4	9.5	9.95	-9%		
614	1	control	0	3	BLOOD	0.5	0.5	0.5	0%		
618	8	Butte	225	3	BLOOD	2.6	2.8	2.7	7%		
606	10	IV	100	3	BLOOD	10.6	11.1	10.85	5%		
628	5	Midvale Slag	225	5	BLOOD	2.6	2.6	2.6	0%		
633	6	Midvale Slag	675	5	BLOOD	5.9	6.1	6	3%		
601	8	Butte	225	5	BLOOD	2.5	2.7	2.6	8%		
610	7	Butte	75	7	BLOOD	2	2	2	0%		
607	10	IV	100	7	BLOOD	10.3	11.7	11	13%		
612	10	IV	100	7	BLOOD	13.6	12.3	12.95	-10%		
630	2	PbAc	75	9	BLOOD	2.7	3.4	3.05	23%		
625	10	IV	100	9	BLOOD	13.8	13.7	13.75	-1%		
642	10	IV	100	9	BLOOD	13.5	13.8	13.65	2%		
644	3	PbAc	225	12	BLOOD	6.9	7.2	7.05	4%		
643	7	Butte	75	12	BLOOD	2.1	1.7	1.9	-21%		
621	8	Butte	225	12	BLOOD	2.4	3.2	2.8	29%		
647	4	Midvale Slag	75	15	BLOOD	2	2.1	2.05	5%		
629	6	Midvale Slag	675	15	BLOOD	6.7	6.9	6.8	3%		
648	10	IV	100	15	BLOOD	15.3	17.2	16.25	12%	10%	**BLOOD**
651	3	PbAc	225	15	FEMUR	21.8	21.6	21.7	-1%		
626	4	Midvale Slag	75	15	FEMUR	1	3.8	2.4	117%		
604	10	IV	100	15	FEMUR	88	73	80.5	-19%	32%	**FEMUR**
614	1	control	0	15	KIDNEY	3.9	4.7	4.3	19%		
618	8	Butte	225	15	KIDNEY	10.8	13.3	12.05	21%		
606	10	IV	100	15	KIDNEY	114	109	111.5	-4%	12%	**KIDNEY**
640	5	Midvale Slag	225	15	LIVER	6.4	7.4	6.9	14%		
615	6	Midvale Slag	675	15	LIVER	15.1	15.8	15.45	5%		
646	9	Butte	675	15	LIVER	21.2	21.3	21.25	0%	6%	**LIVER**

TABLE A-12 CDC STANDARDS

Sample ID	Day	Q	Measured Low Std	Measured Med Std	Measured High Std	Nominal Conc
6.1	-4		1			1.7
6.1	0		1.6			1.7
6.1	1		1			1.7
6.1	3		2			1.7
6.1	9		1.9			1.7
6.2	-4			4.1		4.8
6.2	0			4.7		4.8
6.2	1			4.5		4.8
6.2	2			5.4		4.8
6.2	5			4.9		4.8
6.2	7			6.1		4.8
6.2	12			3.3		4.8
6.2	15			4.4		4.8
6.3	2				14.9	14.9
6.3	3				14.4	14.9
6.3	5				15	14.9
6.3	7				13.5	14.9
6.3	9				14.6	14.9
6.3	12				11.7	14.9
6.3	15				14.4	14.9
Averages			1.5	4.7	14.1	

TABLE A-13 INTERLABORATORY COMPARISON

Tag Number	Pig Number	Group	Material Administered	Dosage	Qualifier		Result		
					CDC	ESD	CDC	ESD	RPD
8-960158	641	2	PbAc	75	U	<	0.6	1	50
8-960174	617	7	Butte	75	U	<	0.6	1	50
8-960208	625	10	IV	100	U	<	0.6	1	50
8-960221	650	5	Midvale Slag	225	U	<	0.6	1	50
8-960249	604	10	IV	100			9.6	6.6	-37
8-960265	609	8	Butte	225		<	1	1	0
8-960313	634	9	Butte	675			3.3	3.2	-3
8-960322	605	5	Midvale Slag	225			1.7	2.2	26
8-960370	615	6	Midvale Slag	675			4.1	3.4	-19
8-960378	626	4	Midvale Slag	75			1.2	1.4	15
8-960401	613	2	PbAc	75			3	4	29
8-960445	628	5	Midvale Slag	225			2.3	2.6	12
8-960452	653	3	PbAc	225			7.9	7.9	0
8-960457	601	8	Butte	225			2.7	2.9	7
8-960511	618	8	Butte	225			3.6	3.3	-9
8-960551	626	4	Midvale Slag	75			1.3	1.3	0
8-960577	630	2	PbAc	75			4.2	2.9	-37
8-960600	623	4	Midvale Slag	75			3.3	3	-10
8-960618	640	5	Midvale Slag	225			2.8	2.2	-24
8-960643	619	4	Midvale Slag	75			4.3	3.6	-18

FIGURE A-1 PbAc and IV Groups by Day
Raw Data

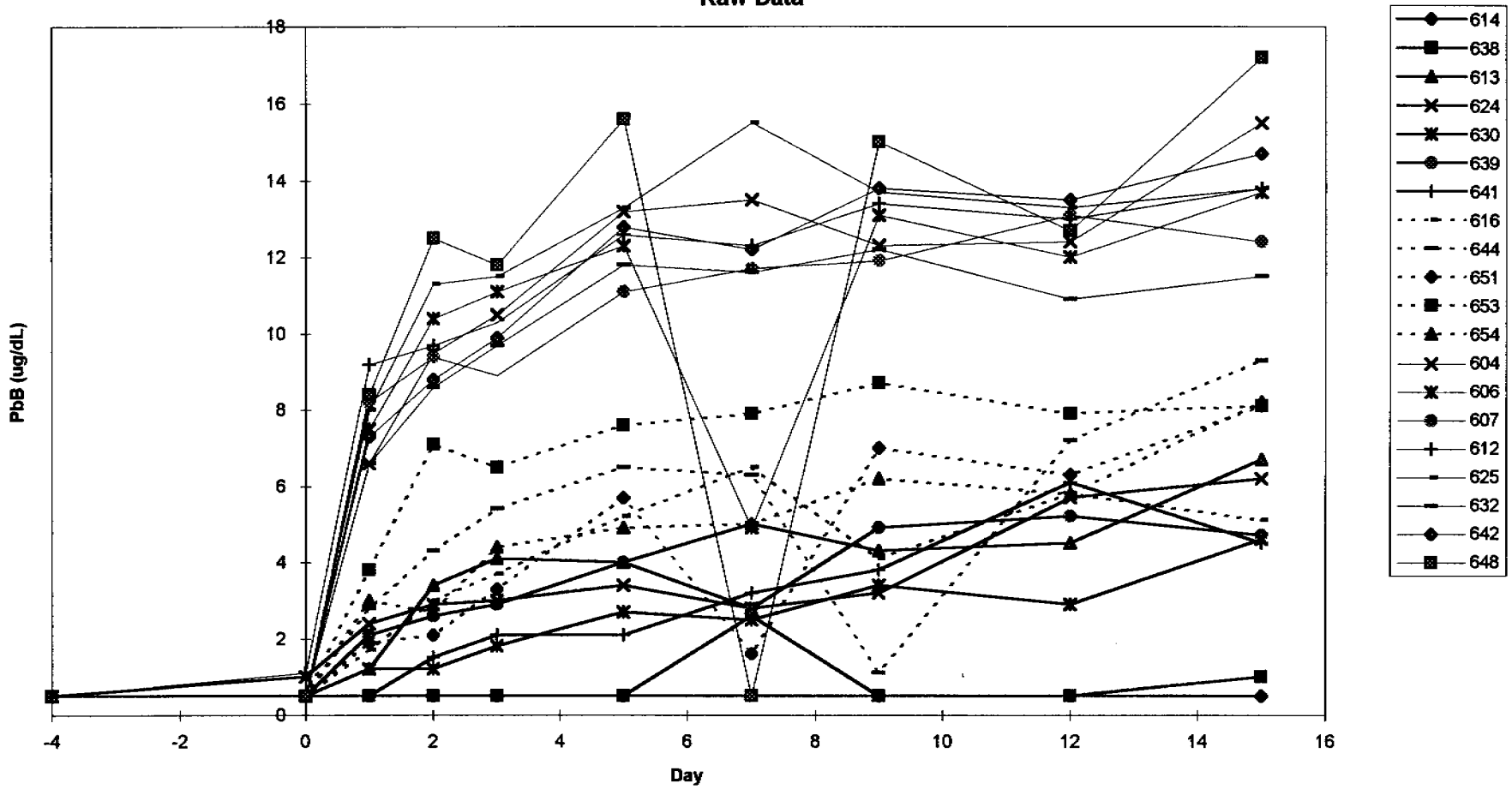


FIGURE A-2 Butte Groups by Day
Raw Data

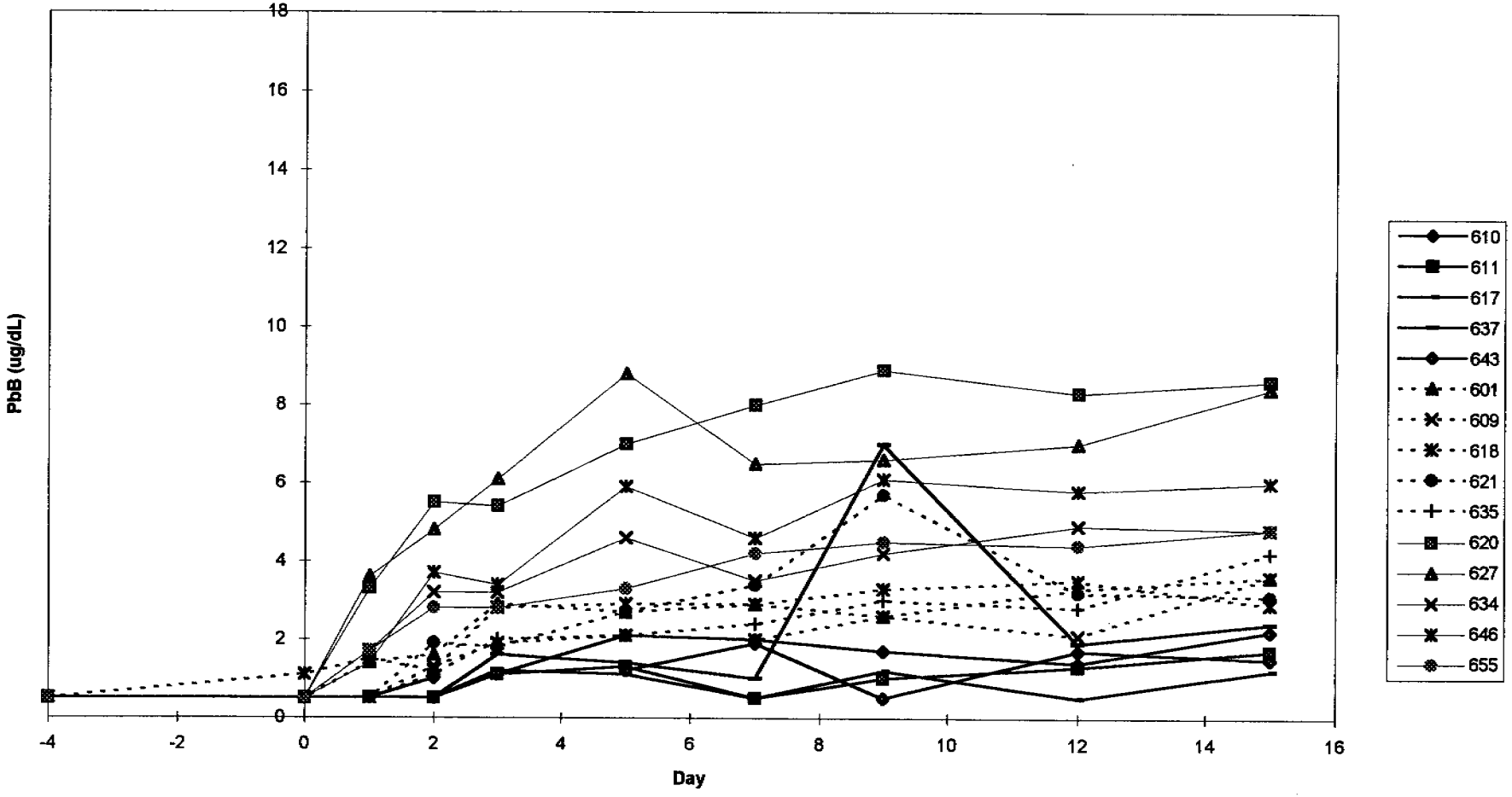


FIGURE A-3 Group Mean PbB By Day
Raw Data

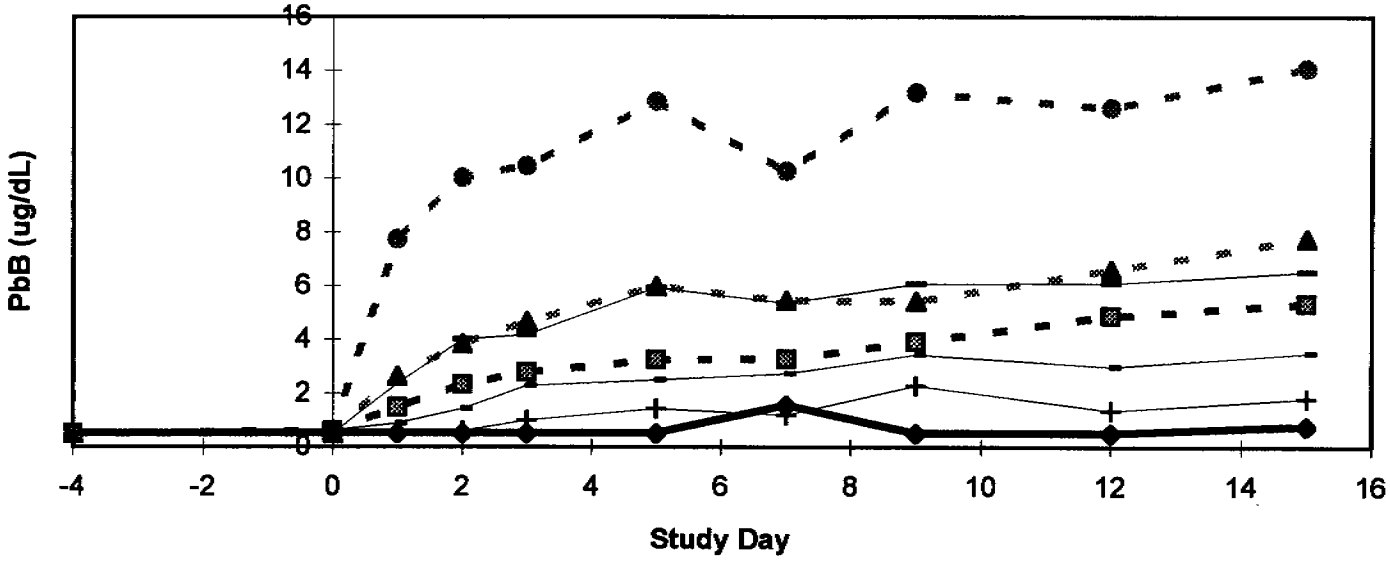


FIGURE A-4

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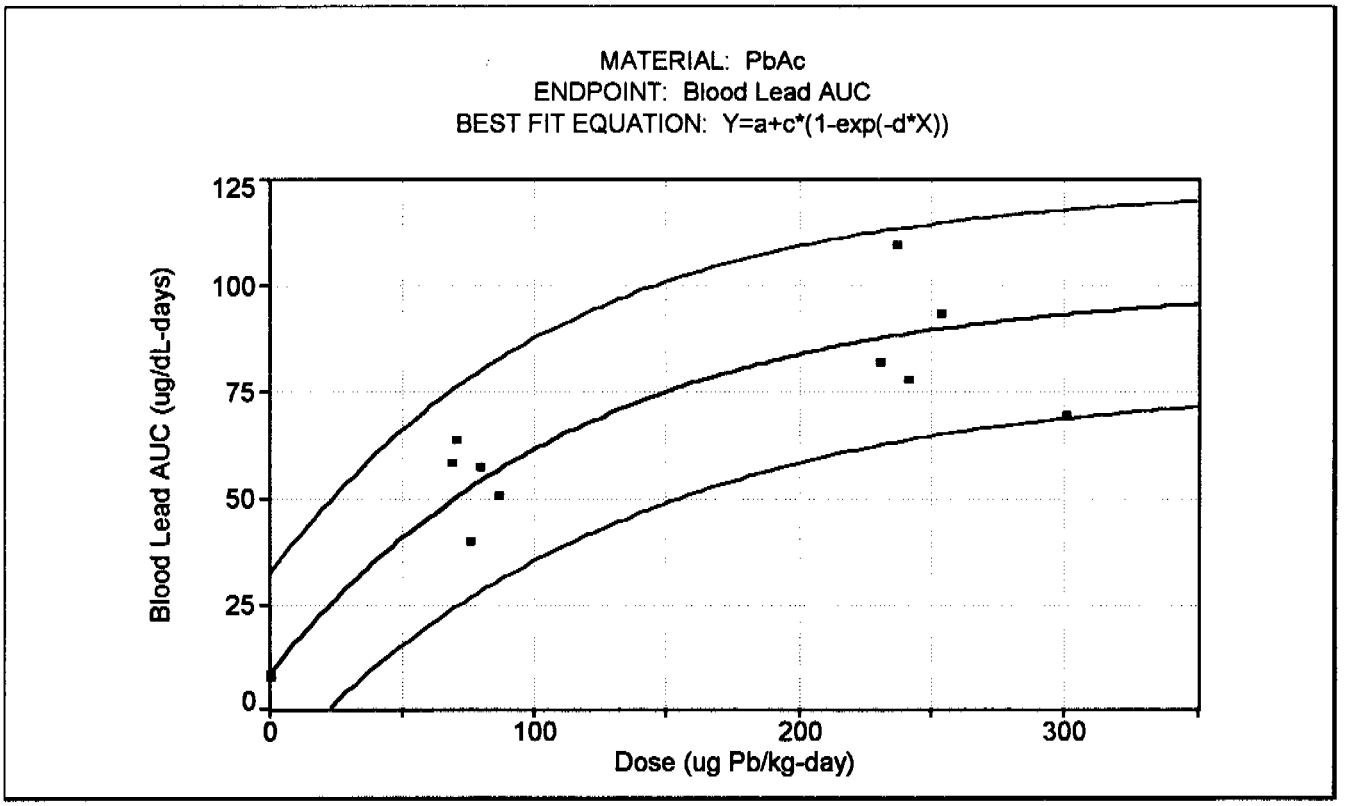
FIGURE A-5 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

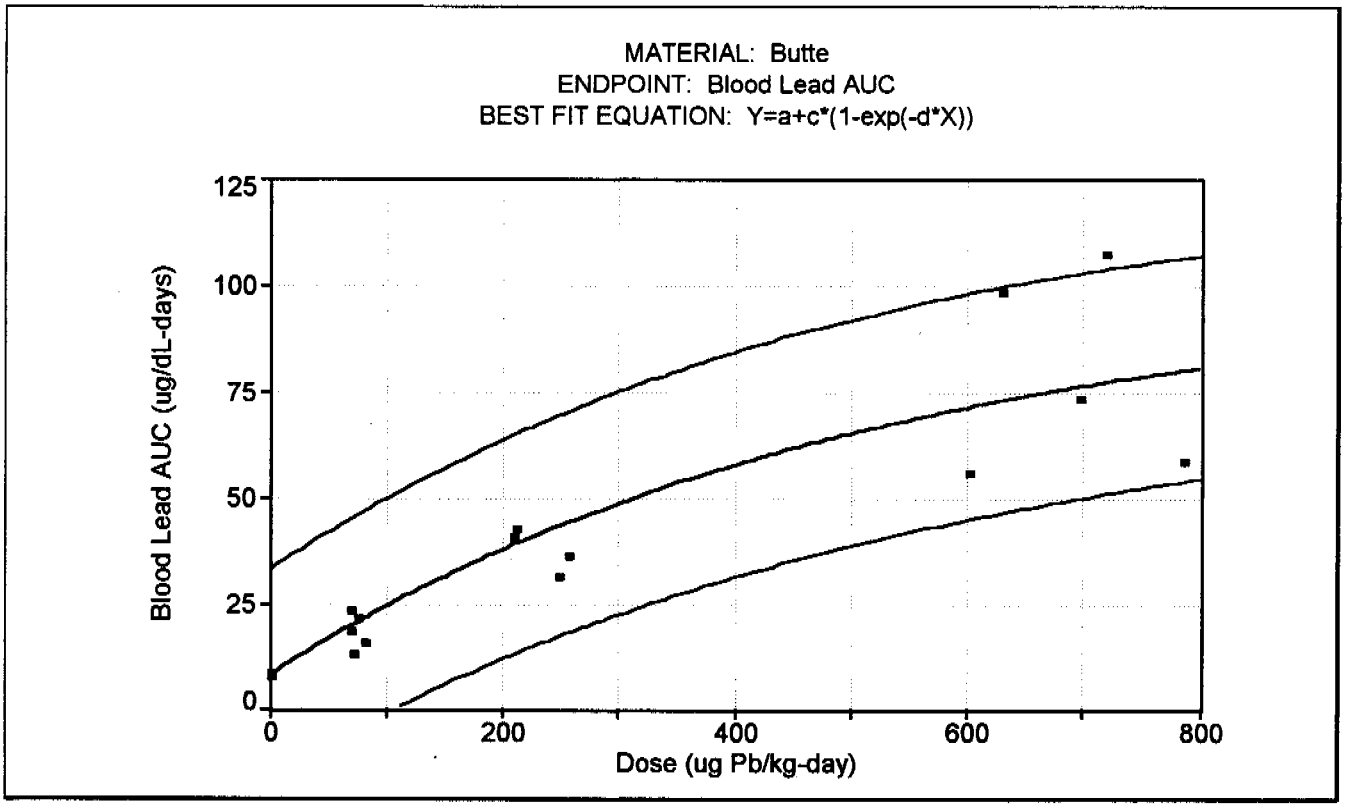


Parameters	Value	Std. Error	95% Confidence Limits	
a	8	fixed value	–	–
c	92	fixed value	–	–
d	0.0086	0.0012	0.0059	0.0113

Adj R^2	0.893

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-6 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

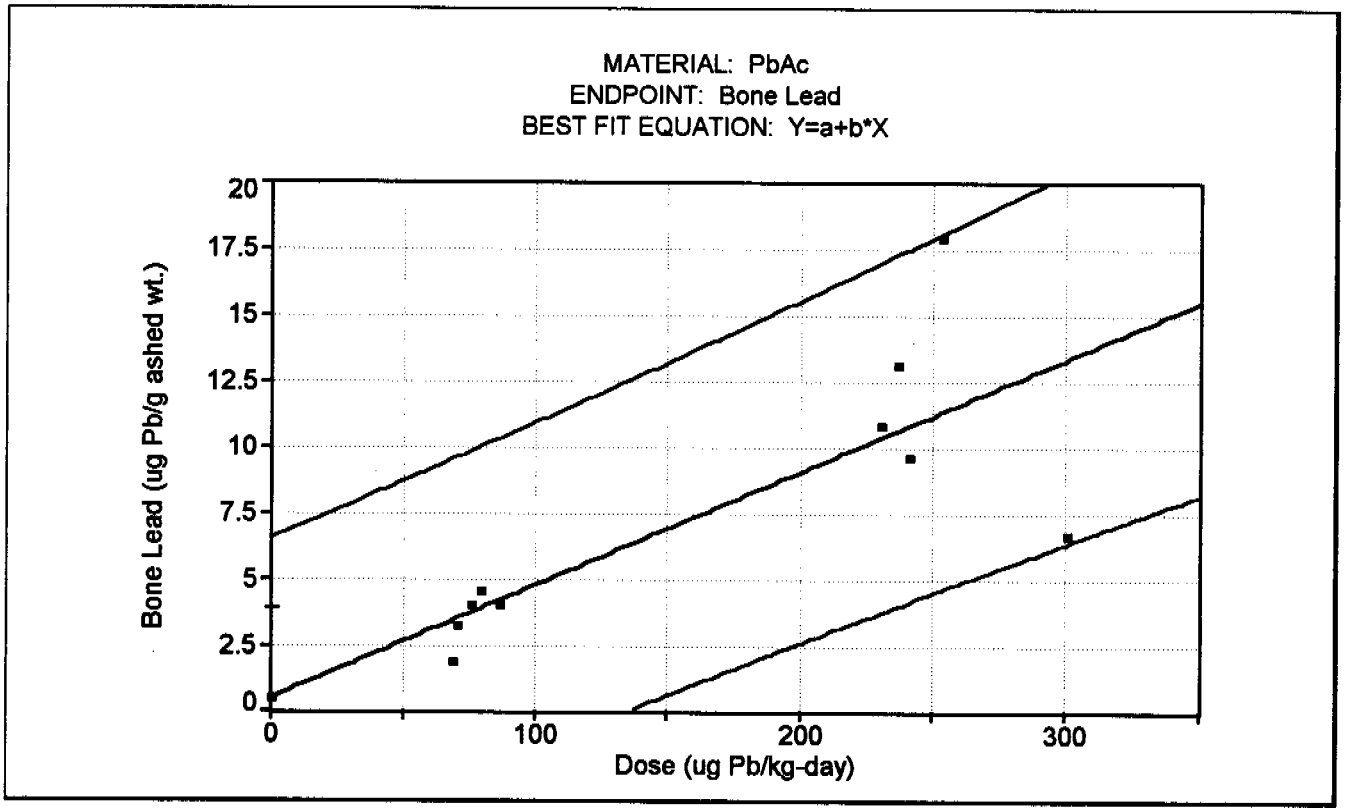


Parameters	Value	Std. Error	95% Confidence Limits	
a	8	fixed value	--	--
c	92	fixed value	--	--
d	0.0019	0.0003	0.0014	0.0025

Adj R^2	0.837

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-7 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

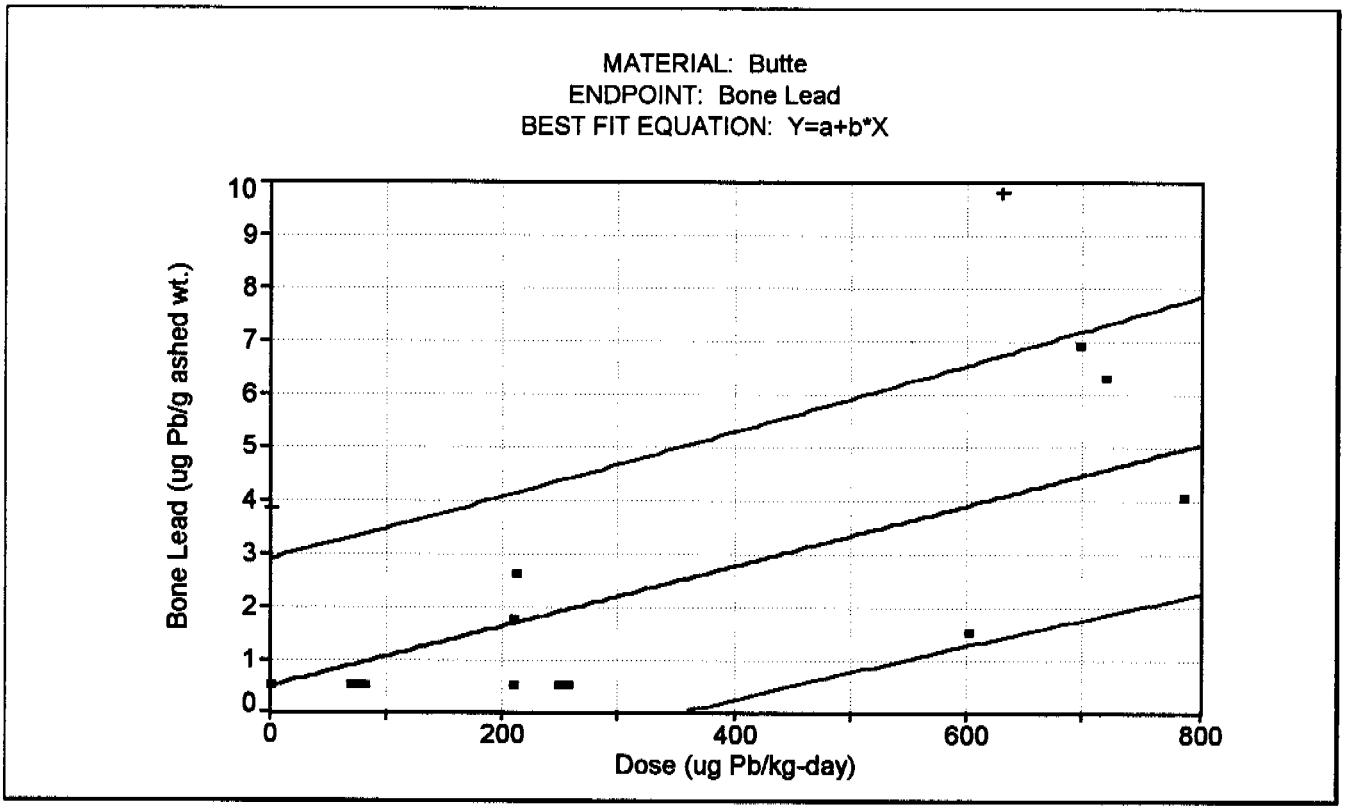


Parameters	Value	Std. Error	95% Confidence Limits	
a	0.45	fixed value	--	--
b	0.043	0.0053	0.031	0.055

Adj R^2	0.727

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-8 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

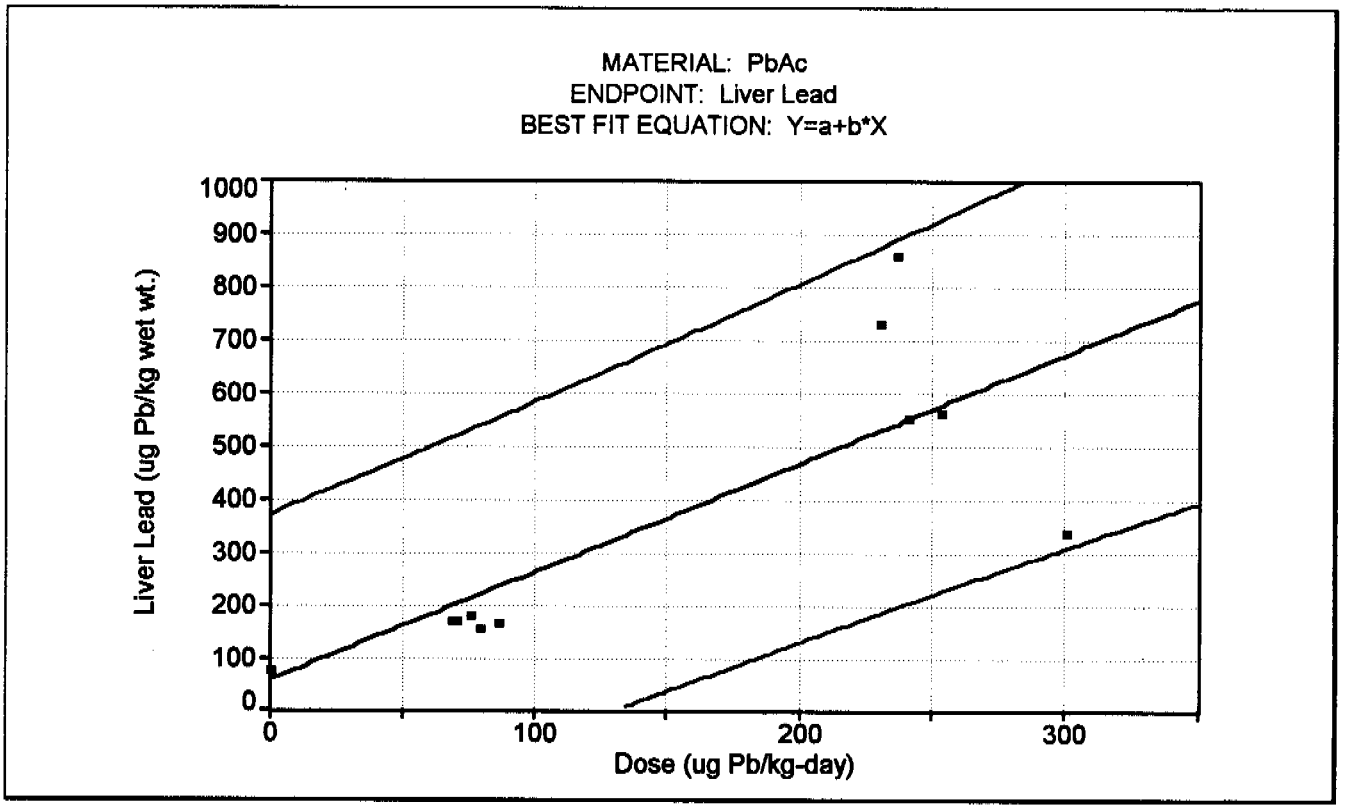


Parameters	Value	Std. Error	95% Confidence Limits	
a	0.45	fixed value	--	--
b	0.0057	0.0008	0.0039	0.0007

Adj R^2	0.669

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-9 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

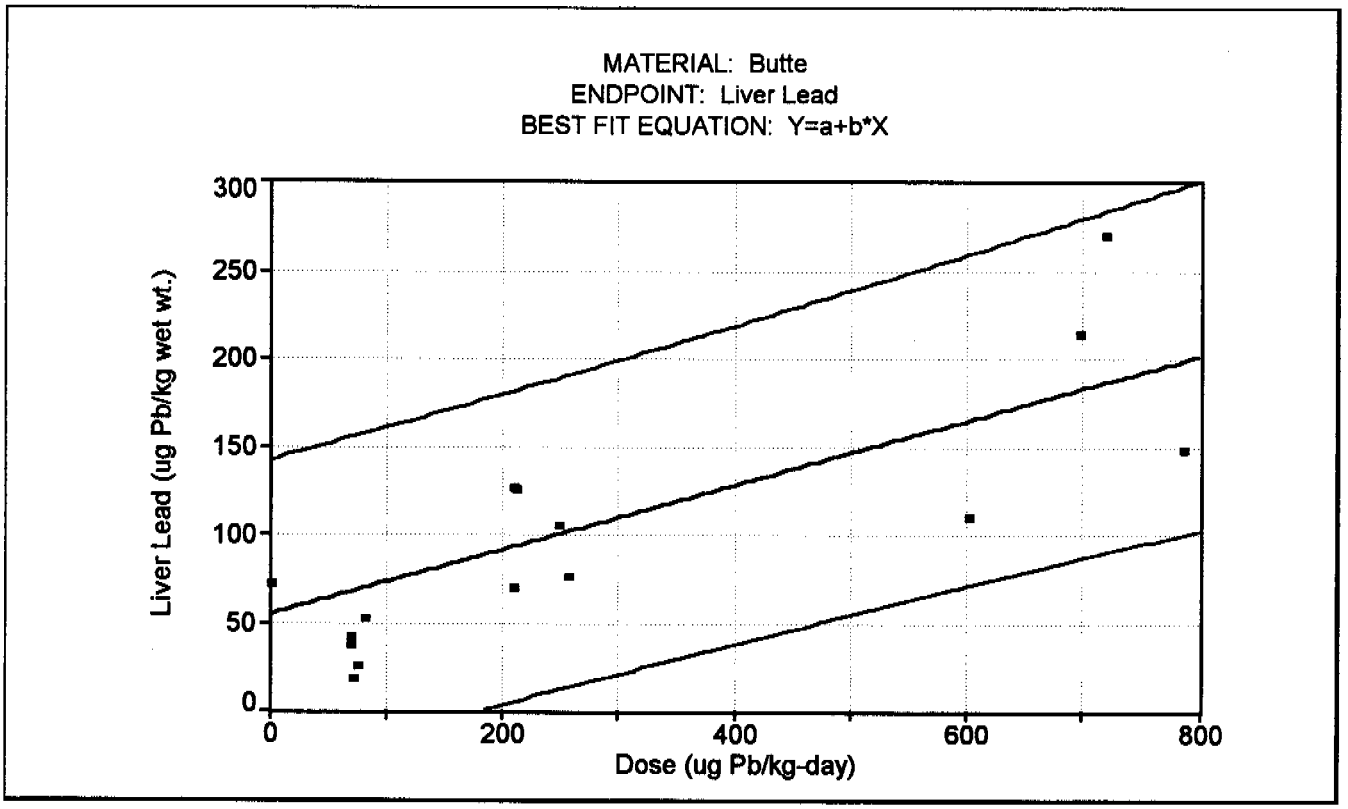


Parameters	Value	Std. Error	95% Confidence Limits	
a	54.4	fixed value	–	–
b	2.05	0.278	1.43	2.67

Adj R^2	0.692

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-10 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

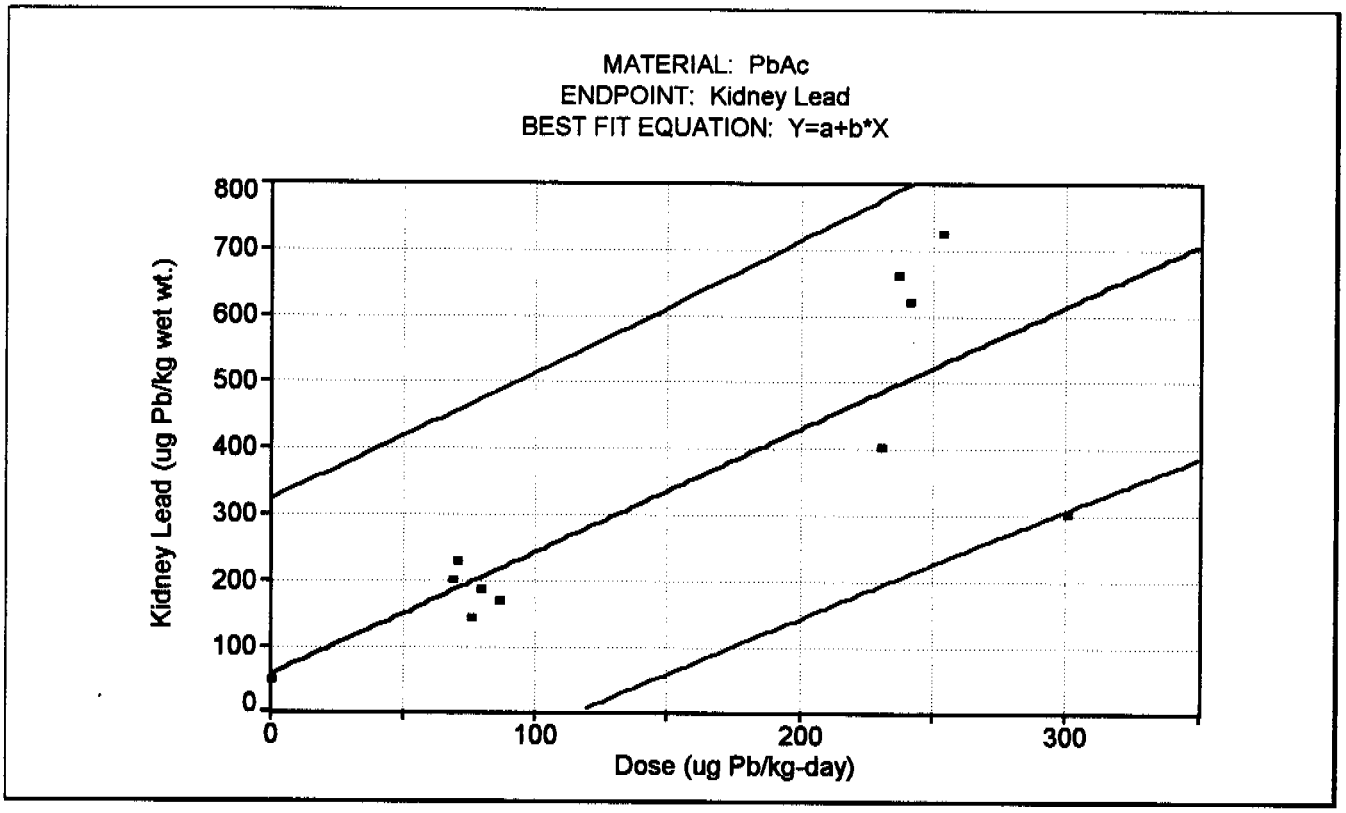


Parameters	Value	Std. Error	95% Confidence Limits	
a	54.4	fixed value	--	--
b	0.183	0.027	0.125	0.241

Adj R^2	0.641

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-11 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*

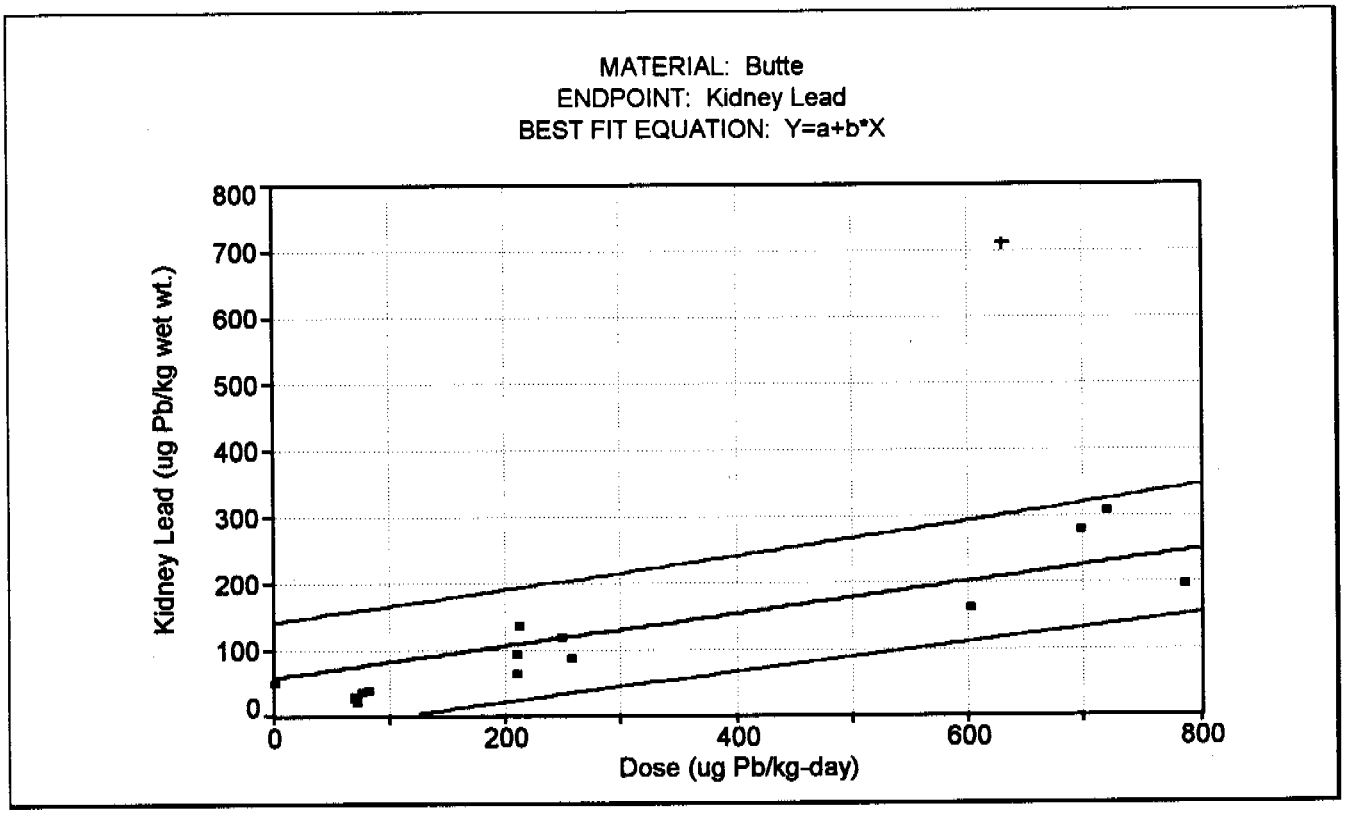


Parameters	Value	Std. Error	95% Confidence Limits	
a	39.5	fixed value	–	–
b	1.86	0.235	1.334	2.382

Adj R^2	0.727

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".

FIGURE A-12 BEST FIT CURVE WITH 95% PREDICTION INTERVALS*



Parameters	Value	Std. Error	95% Confidence Limits	
a	39.5	fixed value	--	--
b	0.24	0.029	0.178	0.302

Adj R^2	0.773

Generated using Table Curve 2D v. 3.0. Outliers represented by "+".